United States Department of the Interior

FISH AND WILDLIFE SERVICE

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Consultation Number 2-15-F-01-0437

Mr. Gregg Cooke
Regional Administrator
U.S. Environmental Protection Agency
1445 Ross Avenue, Suite 1200
Dallas, Texas 75202-2733

Dear Mr. Cooke:

This document transmits the U.S. Fish and Wildlife Service's (Service) biological opinion based on our review of the Environmental Protection Agency's (EPA) continued operation of the Construction General Permit (CGP) for storm water runoff under the National Pollution Discharge Elimination System (NPDES) of the Clean Water Act, as amended (33 U.S.C. 1251). The area under consideration in this consultation is the Barton Springs watershed in Blanco, Hays, and Travis Counties in Texas. We have analyzed the proposed action and its effects on the Barton Springs salamander (*Eurycea sosorum*) in accordance with section 7 of the Endangered Species Act of 1973, as amended (16 U.S.C. 1531 et seq.) (ESA).

This consultation has been assigned the number 2-15-F-2001-0437. Please use this number in all correspondence related to this consultation. EPA's May 2, 2001, request for consultation was received by the Service on May 7, 2001. This biological opinion is based on the information EPA provided; information in our files; field investigations; third party comments on the July 19, 2001, draft biological opinion; information received at the March 27-28, 2002, technical workshops; and other sources of information. A complete administrative record of this consultation is on file at U.S. Fish and Wildlife Service, 107111 Burnet Rd., Suite 200, Compass Bank Bldg., Austin, TX 78758 (Phone: 512/490-0057.)

On September 5, 2001, EPA reviewed the July 19, 2001, draft biological opinion and requested that consultation be limited to effects of the CGP on the Barton Springs salamander. The settlement agreement of April 23, 2001, with the Save our Springs Alliance (SOSA) referenced a consultation only on effects to the Barton Springs salamander, and so we have limited our biological opinion to that species.

Consultation History

On April 28, 1997, EPA entered into consultation with the Service and the National Marine Fisheries Service (NMFS) on issuance of the nationwide CGP. On November 4, and 26, 1997, EPA completed consultation when NMFS and the Service concurred with EPA's finding that issuance of the CGP was not likely to adversely affect listed species or critical habitat.

In February 1998, EPA Region 6 began informal consultation with the Service and NMFS on language to clarify requirements for ongoing construction activity. EPA Region 6 completed informal consultation when the Service and NMFS provided their concurrence on June 9 and 15, 1998, respectively, that issuance of these permits was not likely to adversely affect listed species or critical habitat. EPA Region 6 reissued the CGP which under certain specific conditions authorizes the discharge of storm water associated with construction activity on July 6, 1998.

The Service sent EPA a letter on October 21, 1998, relating concerns about adverse impacts from the CGP in the Barton Springs watershed. The Service reiterated and clarified those concerns in a June 29, 1999, letter to EPA. Discussion occurred between the agencies and several options for addressing the situation were explored between October 1998 and October 1999.

On October 29, 1999, the Texas Capitol Area Builders Association (TxCABA) filed a lawsuit against the Service in the U.S. District Court, Western District of Texas, Austin Division (U.S. District Court), alleging violations of the Clean Water Act and the ESA. The original complaint focused on the October 21, 1998, and June 29, 1999, letters that the Service had written to EPA. On November 21, 1999, TxCABA amended the original complaint with allegations related to a biological opinion that the Service issued on EPA's NPDES Municipal Separate Storm Sewer System permit to the City of Austin.

On June 15, 2000, the SOSA filed a lawsuit against EPA and the Service in U.S. District Court alleging violations of the Clean Water Act and the ESA. The SOSA complaint focused on the adequacy of the consultation process on the CGP and their belief that protective measures for the Barton Springs salamander were lacking.

On August 17, 2000, the U.S. District Court ordered the two cases be combined. On March 14, 2001, a settlement agreement was filed on the TxCABA portion of the case. The TxCABA settlement agreement remanded the biological opinion on City of Austin's Municipal Separate Storm Sewer System permit. The terms of that settlement agreement are still outstanding. On April 23, 2001, a settlement agreement was filed on the SOSA portion of the case. As part of the SOSA settlement agreement, EPA agreed to initiate the consultation with the Service on the continued operation of the CGP in the Barton Springs watershed. EPA's request to initiate consultation was received on May 7, 2001. Additional information related to the consultation was received on June 7, 2001. On July 19, 2001, the Service provided a draft biological opinion to EPA. On August 21, 2001, EPA provided third party comments on the draft to the Service from a variety of interested parties.

During a telephone conference on August 15, 2001, representatives of the USFWS, Headquarters and Region 2 offices, along with EPA, Headquarters and Region 6 offices, agreed to meet in Washington, D.C. on September 5, 2001, to further discuss the draft biological opinion and alternatives. During the meeting, the Service and EPA jointly agreed that the draft biological opinion would benefit from further review.

EPA provided suggested areas for review on the draft biological opinion on November 6, 2001. On December 17, 2001, the SOSA refiled their lawsuit against EPA and the Service in U.S. District Court. On February 28, 2002, EPA, Region 6 and USFWS, Region 2 agreed on a schedule for expediting the completion of consultations. On March 26, 2002, the U.S. District Court issued an order for EPA and the Service to conclude this consultation within 40 days.

EPA and USFWS jointly held a technical workshop on March 27 and 28, 2002, at the Marriot Austin Airport. The workshop focused on the hydrology and water quality of Barton Springs Recharge and Contributing Zones as well as on the biology of the Barton Springs salamander.

BIOLOGICAL OPINION

I. Description of Proposed Action

The proposed action is the continued operation of EPA's CGP within the Barton Springs watershed in Texas.

EPA Region 6 reissued the CGP which authorizes the discharge of storm water associated with construction activity on July 6, 1998. This permit will expire on July 7, 2003, at which time administration of the CGP will be assumed by the State of Texas and ESA compliance will be provided via the September 14, 1998, biological opinion on the State's assumption of the NPDES program. As stated at 40 CFR §122.26(b)(14)(x), and in the permit, "storm water associated with construction activity" means construction activity disturbing at least five acres, or construction activity disturbing less than five acres which is part of a larger common plan of development or sale with the potential to disturb cumulatively five or more acres. EPA retains jurisdiction over the site until it is 70% vegetated or permanently stabilized.

The CGP requires that applicants consider effects to listed species and critical habitat when developing Storm Water Pollution Prevention Plans and requires that those plans include measures, as appropriate, to protect those resources. Failure by permittees to abide by measures in the Storm Water Pollution Prevention Plans to protect species and critical habitat may invalidate permit coverage.

The CGP requires all project applicants to follow the procedures provided in Addendum A of the permit when applying for permit coverage. The EPA Administrator may also require any existing permittee or applicant to provide documentation of eligibility for this permit where EPA, the Service, or NMFS determine that there is a potential impact on endangered or threatened species or critical habitat. Nothing in the permit relieves applicants with projects under construction as of the effective date of this permit of obligations to comply with any requirements of the ESA.

Addendum A of the CGP contains instructions to assist permit applicants in making the endangered species inquiry. Those instructions require that applicants ascertain whether: (1) construction activities would occur in critical habitat, (2) listed species are in the project area, and (3) the applicant's storm water discharges and discharge-related activities are likely to adversely affect listed species or critical habitat. If adverse effects are likely, then applicants would have to meet one of the eligibility requirements of Part I.B.3.e of the permit to receive coverage. "Discharge-related activities" include activities which cause point source storm water pollutant discharges including, but not limited to, excavation, site development, and other surface disturbing activities, and measures to control, reduce or prevent storm water pollution including the siting, construction, and operation of Best Management Practices. The project area varies with the size and structure of the construction activity, the nature and quantity of the storm water discharges, the measures to control storm water runoff, and the type of receiving waters.

The CGP requires that applicants comply with any conditions imposed under the eligibility requirements of Part I.B.3.e.(2) of the permit to remain eligible for coverage. Such conditions must be incorporated in the applicant's Storm Water Pollution Prevention Plan. The CGP does not authorize any take (as defined under section 3 of the ESA and 50 CFR §17.3) of endangered or threatened species, unless such take is permitted under sections 7 or 10 of the ESA. The CGP does not authorize any storm water discharges or storm water discharge-related activities that are likely to jeopardize the continued existence of any species that are listed or proposed to be listed as endangered or threatened under the ESA or result in the adverse modification or destruction of habitat that is designated or proposed to be designated as critical under the ESA.

Thus, EPA allows applicants to use either section 7 or 10 ESA mechanisms to address situations where adverse effects are likely (Part I.B.3.e.[2] of the CGP). Also, to give applicants additional flexibility in meeting the Part I.B.3.e eligibility requirements and in the timing of informal consultations, the permit automatically designates CGP applicants as non-Federal representatives for the purpose of carrying out informal consultation with the Service. As an alternative to seeking coverage under EPA's CGP, finally, an applicant may apply to the State of Texas for an individual NPDES permit.

EPA placed the following conditions in the permit (Part I.B.3.e) to protect listed species and critical habitat. Coverage under the CGP was made available for construction projects only if:

a. The storm water discharges and storm water discharge-related activities are not likely to adversely affect listed species or critical habitat; or

b. Formal or informal consultation with the Service or NMFS under section 7 of the ESA has been concluded which addresses the effects of the applicant's storm water discharges and storm water discharge-related activities on listed species and critical habitat and the consultation results in either a no jeopardy opinion or a written concurrence by the Service or NMFS on a finding that the applicant's storm water discharges and storm water discharge-related activities are not likely to adversely affect listed species or critical habitat. A section 7 consultation may occur in the context of another Federal action (e.g., a section 7 consultation was performed for issuance of a wetlands dredge and fill permit for the project, or as part of a National Environmental Policy Act analysis); or

c. The applicant's construction activities are covered by a permit under section 10 of the ESA and that permit addresses the effects of the applicant's storm water discharges and storm water discharge-related activities on listed species and critical habitat (Part I.B.3.e.[2][c]); or

d. The applicant's storm water discharges and storm water discharge-related activities were already addressed in another operator's certification of eligibility under Part I.B.3.e.(2)(a), (b), or (c) which included the applicant's project area. By certifying eligibility under Part I.B.3.e.(2)(d), the applicant agrees to comply with any measures or controls upon which the other operator's certification under Part I.B.3.e.(2)(a), (b), or (c) was based.

The CGP requires erosion and sediment and other pollutant controls (e.g., silt fences, buffer strips, sediment traps, temporary stabilization, proper materials storage and handling, sediment removal from streets, spill prevention and response, trash and other debris control) throughout the "active" phase until final stabilization. The CGP requires temporary or final stabilization be started within 14 days if a disturbed area will not be re-disturbed for 21 days. CGP controls will thus always be in place, but the percent "stabilized" within a project at any one point in time will vary widely according to which area has been: (1) not yet disturbed, (2) currently disturbed because it is actively being worked, (3) temporarily stabilized, (4) temporarily stabilized and has now been re-disturbed, and (5) completed and has been finally stabilized. As the size and duration of a project increases, differing percentages of the project will range from undisturbed, temporarily stabilized, or permanently stabilized through the project life. EPA expects that only the smallest projects, which are not part of a larger common plan of development or sale, would be likely to contain a large percentage of disturbed areas for the majority of the project term. Larger projects with multiple operators, such as a multi-phase master-planned residential development, would be more likely to have only a fraction of the total project area disturbed at any one time.

A construction project following CGP requirements and EPA recommendations (EPA 1992, 1998) would adopt Best Management Practices to: minimize the amount of disturbed soil, prevent runoff from offsite areas (or other portions of the same project) from flowing across disturbed areas, slow down the runoff flowing across the site, remove sediment from onsite runoff before it leaves the site, remove sediment from local streets, provide temporary stabilization for areas that were not being redisturbed within 21 days, provide permanent stabilization for completed areas, meet or exceed local or state requirements for sediment and erosion control plans, reduce pollutants form materials storage areas, and prevent and respond to spills.

EPA develops NPDES permits under the presumption of full compliance by permittees, The CGP requires submission of an administratively complete (properly filled out) NOI to a national processing center in Washington, DC in order to be authorized to discharge under the permit. Permit coverage is "automatically" effective 48 hours after the NOI postmark date if the NOI is "complete" and the operator has met the eligibility conditions of the permit. At the NOI processing center, each NOI is checked for completeness and EPA notifies operators that have not certified they meet the permit's eligibility conditions regarding endangered species protection that they are not covered by the permit. If the NOI is complete and the operator has certified that they meet the permit eligibility conditions, construction may begin without EPA independently verifying the accuracy of the operator's certified claim of eligibility with regard to endangered species protection. Any discharges prior to the submission of a complete NOI are not authorized by the CGP. EPA has inspected or investigated numerous construction projects in the Barton Springs watershed. Many of these inspections or investigations have been triggered by citizen complaints or information provided by the Service's Austin Ecological Services Field Office. EPA has taken enforcement actions for violations regarding construction projects in the Barton Springs watershed.

The Service and EPA have determined that the action area for this consultation is the Barton Springs watershed (Figure 1) which encompasses: (1) the four springs and spring runs (collectively referred to as Barton Springs), (2) the underground aquifer that provides water to the spring outlets, (3) the land within the watersheds that contribute to Barton Springs, and (4) the surface water streams (Barton, Williamson, Slaughter, Bear, Little Bear, and Onion Creeks) in the recharge and contributing areas of the aquifer. Several areas within this zone do not directly recharge to Barton Springs (Hauwert et al. 1998). However, water routinely passes through these areas and recharges Barton Springs. Therefore, the entire watershed is included in the action area.

II. Status of the Barton Springs Salamander

The Barton Springs salamander is known only from Barton Springs in Zilker Park, in Austin, Texas (62 FR 23377). Critical habitat has not been designated for the salamander. The salamander is aquatic in all life stages and has one of the smallest geographical ranges of any vertebrate in North America (Aquatic Biological Advisory Team 1995). The salamander was listed as endangered on May 30, 1997 (62 FR 23377). In the final rule listing the salamander, the primary threats or reasons for listing were identified as the degradation of the quality and quantity of water that feeds Barton Springs resulting from urban expansion over the watershed. These threats were projected to result in the "destruction, modification, or curtailment of the species habitat or range." Factors contributing to these threats include "chronic degradation, catastrophic hazardous materials spills, increased water withdrawals from the aquifer, and impacts to the surface habitat" (62 FR 23377).

Population estimates for the salamander are not available because the aquifer is not accessible to humans. Estimates based on mark-recapture are not possible because the technology to safely and reliably mark salamanders for individual recognition has not been developed. However, historic information indicates the salamander was abundant prior to the 1980s (Chippindale et al. 1993). The highest observed number in the main pool was recorded as over 150 individuals found on a two-hour dive in November 1992 (Chippindale et al. 1993). Subsequent comprehensive surveys with three to four people over about two hours (six to eight hours total effort) found 26 (October 1994), 11 (March 1995), 39 (March 1998), 46 (April 1998), 49 (June 1998), and 71 (August 1998) salamanders.

City of Austin biologists initiated monthly scuba surveys at Barton Springs Pool in 1993, but have had to change methods due to the increasing difficulty of finding salamanders. From 1993 to October 1994, City biologists surveyed along six transects, stopping every ten feet and searching within a one square meter area, as well as "hot spots" (springs and fissures). Following a flood in October 1994, much of the habitat was lost due to sedimentation. The survey method was intensified to include 1.5 feet on either side of the entire transect, which greatly increased the survey area. Beginning in October 1997, methods gradually shifted from transects to the immediate area around the springs and fissures because the transect method was becoming less productive. Monthly surveys conducted since 1993 using these methods have ranged from 1 to 82 individuals (City of Austin 1998a, unpublished data 1993-2001). Counts have documented less than 30 salamanders since May 2000.

Salamanders are most frequently discovered around the main spring outflows, hidden within a 2 to 8 cm (0.8 to 3.1 inches) deep zone of gravel and small rocks overlying a coarse sandy or bare limestone substrate. These areas are noticeably clear of fine silt or decomposed organic debris near spring discharge points and appear to be kept clean by the briskly flowing spring water during medium to high aquifer levels. Abundant prey species for the salamander also inhabit these areas. Piles of woody debris in the vicinity of the main springs provide habitat for the salamander as well as its prey base. Barton Springs serves as a swimming pool for humans and salamanders are found on the beach area and around minor spring outlets within the limestone fissures, just west of the diving board. Suitable habitat can increase or decrease depending on such factors as springflows, abundance of aquatic macrophytes, sedimentation rates, and frequency of floods.

"Dozens or hundreds" of individuals were found at Eliza Spring during the 1970s (Chippindale, et al. 1993). Numbers observed since 1987 have varied from 0 to 188 (Chippindale et al. 1993; City of Austin and Service, unpublished data, 1995-2001). The highest number of salamanders (188) was observed in 1997 following drawdown of the water level. The highest number observed during a routine survey was 59 in March 1997 (City of Austin 1998a, unpublished data

1995-2000). The water level in Eliza Spring was shallow enough during these early surveys that biologists could count salamanders by looking through the surface of the water or using snorkeling equipment. Although salamander numbers vary, the detection of them has steadily declined despite increased survey efforts using scuba gear. Since September 1999, the highest salamander count has been 7, and often none are found. Eliza Spring reportedly had little or no sediment prior to the early 1990s (D. Hillis and J. Reddell, University of Texas at Austin, pers. comm. 1996-2002). Sediment accumulations have been an increasing problem, and thick layers cover the entire pool.

Salamanders have been found sporadically in the bottom of Old Mill Spring, its spring run, and the confluence of the spring run and Barton Creek. Salamanders are difficult to find at Old Mill Spring due to the deep layer of large rocks that covers the bottom of the springs, which makes it easier for salamanders to escape and hide. Numbers observed at Old Mill Spring have varied from 0 to 67 (City of Austin and Service, unpublished data 1996-2001).

In April 1997, City of Austin and Service staff discovered 14 adult salamanders at Upper Barton Spring, which flows intermittently. Numbers of salamanders since that time have ranged from 0 to 14 at this site (City of Austin 1998a, unpublished data 1997-2000). Cold Springs, Campbell's Hole, and Backdoor Springs are spring sites discharged by the Barton Springs watershed. Campbell's Hole and Backdoor Spring are in Barton Creek. Cold Springs discharges directly to the Colorado River in Town Lake. Various survey attempts at these springs have failed to locate salamanders. No salamanders have been found at any other sites in the Barton Springs watershed (Chippindale et al. 1993, Russell 1996, City of Austin 1998a). On February 5, 2002, an aquatic *Eurycea* salamander (same genus as the Barton Springs salamander) was observed by the Service in a spring in the Bear Creek watershed. To date the Service has not had access to that site to determine the species of salamander inhabiting that spring.

We do not know the extent of the salamanders distribution into the aquifer (City of Austin 1998a). Since food supplies are more limited in the aquifer due to the absence of photosynthesis, salamanders are likely concentrated near spring openings where food is abundant, water chemistry and temperatures are relatively constant, and where salamanders have immediate access to both surface and subsurface (Chippindale et al. 1993).

The salamander appears to be an opportunistic feeder, consuming live invertebrates small enough to catch and swallow. Chippindale et al. (1993) reported finding amphipod (*Hyalella azteca*) remains in the stomachs of wild-caught salamanders. The gastrointestinal tracts of 18 salamanders found dead in the wild contained ostracods, copepods, midge larvae, snails, amphipods, mayfly larvae, leeches, and beetles (City of Austin unpublished data 1999). A list of invertebrates found at Barton Springs is provided in Table 1.

Between January 28 and April 17, 2002, 14 Barton Springs salamanders have been found at Upper Barton Springs with internal and external gas bubbles throughout their bodies (City of Austin unpublished data). This condition is characteristic of a disorder known as gas bubble disease or gas bubble trauma (Bouck 1980; Crunkilton et al. 1980; Finckeisen et al. 1980; Montgomery and Becker 1980; Weitkamp and Katz 1980; Colt et al. 1984a, 1984b; Krise and Smith 1993; Kruse 1993; Fidler and Miller 1994; Mayeaux 1994). External bubbles (emphysema) may produce lesions and tissue necrosis due to inflation of mucous membranes, skin, and fins, which in turn can lead to secondary infections (Fidler and Miller 1994). Death appears to be the result of an accumulation of internal bubbles (emboli) in the cardiovascular system (Weitkamp and Katz 1980, Fidler and Miller 1994). Of the 14 salamanders affected, 9 were found dead or died shortly after they were found. In addition to the salamanders, several Mexican tetras (*Astyanax mexicanus*), mosquito fish (*Gambusia affinis*), leopard frog (*Rana berlandieri*) tadpoles, and crayfish (*Procambrus clarki*) have also exhibited symptoms of gas bubble trauma. Two affected Barton Springs salamanders were also observed at Old Mill Spring on April 10 and 11, 2002 (City of Austin unpublished data). The phenomenon is being investigated by the City of Austin, the Service, EPA, TNRCC, and the U.S. Geological Survey (USGS).

Based on information obtained from the literature (Bouck 1980, Crunkilton et al. 1980, Finckeisen et al. 1980, Montgomery and Becker 1980, Nebeker et al. 1980, Weitkamp and Katz 1980, Colt and Brooks 1984, Colt et al. 1984a, Krise and Smith 1993, Kruse 1993, Fidler and Miller 1994, Mayeaux 1994), gas bubble trauma is caused by supersaturation of water with dissolved atmospheric gases (nitrogen, oxygen, and trace gases, including argon and carbon dioxide). Percent supersaturation is high at all four of the spring sites, but highest at Upper Barton (up to 125%) and lowest at Eliza and Main springs (about 110%). Percent supersaturation in a well along the flowpath to Upper Barton Spring had the highest reading (over 160%) among several wells, springs, and creeks sampled in the Barton Springs watershed (City of Austin, USGS, Service, unpublished data).

Anthropogenic factors contributing to supersaturation include hydroelectric dams, warm water discharges from cooling facilities, algal blooms, and air or gas injection by pressurized pumps. Supersaturation of many wells and springs has also been attributed to natural causes. Supersaturated groundwater may result from high pressures and/or increases in temperature as the water surfaces (Weitkamp and Katz 1980, Fidler and Miller 1994). However, no occurrence of gas bubble trauma in organisms that are endemic to these naturally-occurring supersaturated environments have been reported.

Although baseline data of total dissolved gases is not available for the Barton Springs watershed, the appearance of bubbling or degassing at Upper Barton Springs is not a recent phenomenon, indicating the waters are typically supersaturated at this site. Water chemistry data, including pH, dissolved oxygen, temperature, and specific conductance (City of Austin, unpublished data), do not indicate denitrification or other anthropogenic causes of supersaturation. Prior to this incident, there has been no evidence of gas bubble trauma at this site (City of Austin, unpublished data).

The Service continues to study possible causes of gas bubble trauma found in Barton Springs salamanders. Studies of atrazine (Allran and Karasov 2001) and fuel oil (McGrath and Alexander 1979) suggest these compounds may affect respiration and gas exchange in tadpoles. A study of elevated nitrate and nitrite showed sublethal effects that included disequilibrium and bent tails in tadpoles and a larval salamander (Marco et al. 1999). The Service is concerned that triazine herbicides (atrazine and simazine), polyaromatic hydrocarbons (PAHs), solvents, and elevated levels of nitrate have been found in water and sediment samples from Upper Barton Springs (City of Austin and USGS, unpublished data). The likely synergistic effects of these pollutants in concert with supersaturated waters requires evaluation.

III. Environmental Baseline

The entire range of the salamander is within the action area.

Local Ordinances

Local governments have implemented a variety of land use controls which affect the quality and quantity of storm water post-construction (Table 2).

Village of Bee Caves Ordinance - Chapter 9 of the Villages' Codes and Regulation is the subdivision ordinance that was adopted in 1987 and amended in 2000 and 2001. This ordinance defines both major and minor waterways and prevents location of a lot line within 100 feet of the centerline of any major or minor waterway. Chapter 12 of the codes and regulations, adopted in 1994 and amended in 2000, regulates land use, plats, plans, and subdivisions of land within the Village. The Village adopted and amended a non-source pollution control ordinance as part of Chapter 11 in 2000 and 2001 to establish management policies governing planning, design, construction, operation, and maintenance of drainage, erosion, and water quality control facilities within the Village and its Extraterritorial jurisdiction. Impervious cover is limited to 20% for single-family residential use and 40% for multi-family and nonresidential uses. However, provisions for increased density are provided in the ordinance. Water quality buffer zones are located along all waterways and extend a minimum of 85 feet for all waterways having at least 30 acres of watershed. Water quality buffer zones in Little Barton and Barton Creeks extend a minimum of 300 feet on each side of the waterway. All critical environmental features have buffers extending a minimum of 85 feet.

Save Our Springs (SOS) Ordinance - The City of Austin protects water quality through its Land Development Code. Watershed ordinance requirements include setbacks from creeks and critical environmental features, erosion control, revegetation, impervious cover limitations, and storm water treatment. Approximately 29% of the Barton Springs watershed falls within Austin's extraterritorial jurisdiction and is subject to the requirements of several layers of ordinances often collectively referred to (at least in the watershed) as the SOS ordinance (approximately 72% of the Travis County and 6% of the Hays County portions make up the 29% under Austin's jurisdiction) (Lower Colorado River Authority [LCRA] 2001). The ordinances were in place in 1992. The SOS Ordinance is required in the City of Austin jurisdiction, which covers about 29%

of the watershed. Within the Austin portion of the Barton Springs watershed, approximately 790 acres were exempt from the SOS Ordinance by a clause in Texas House Bill 1704.

Dripping Springs Ordinance - While the incorporated area of the City of Dripping Springs encompasses only 0.8% of the Barton Springs watershed, its extraterritorial jurisdiction covers an additional 28.9%, totaling over 71,000 acres. The City of Dripping Springs ordinances utilize a mix of setbacks from waterbodies and sensitive environmental features, lot density maximums, impervious cover limitations, restrictions on building on slopes over 35% gradient, and requirements for sediment and erosion control. The ordinances were passed in 1995.

State Rules

Edwards Aquifer Rules (Texas Water Code, Chapter 213) - The TNRCC's Edwards Aquifer Recharge, Transition, and Contributing Zone Rules (Edwards Aquifer Rule) apply to all areas within the Barton Springs watershed. These rules apply to projects that are part of a common plan of development or sale that disturbs 5 or more acres, the same universe of construction activities regulated under the CGP. However, construction of a single family residence on 5 or more acres where impervious cover will not exceed 20% is exempt from the requirement to submit a plan for approval. Developments with 20% or more impervious cover must include structural controls to remove 80% of the post-construction incremental increase in the annual load of total suspended solids (TSS).

Regulations for the protection of the water quality in the Edwards Aquifer were promulgated for the recharge and buffer zones in portions of Kinney, Uvalde, Medina, Bexar, Comal, and Hays Counties. Important dates in the history of the Edwards Aquifer regulations between July 31, 1970 and the present are shown in Table 3.

Texas House Bill 76(R)HB1704 - The bill states that development must comply with the requirements that were in place at the time when the first permit application for that development was filed. Development which had received a permit prior to imposition of more recent land use controls was not required to implement those controls mid-project. Within the Austin portion of the Barton Springs watershed, approximately 798 acres were affected through the year 2000 (LCRA 2001).

Texas Senate Bill SB873 SUBCHAPTER E - Senate Bill 873 was amended by the Senate and the House to incorporate Subchapter E and was effective on September 1, 2001. This subchapter authorizes urban counties to adopt subdivision regulations. It includes lot size and setback limitations. It authorizes counties to enforce a major thoroughfare plan and establish rights-of-way. The bill also allows counties to require possession of a plat compliance certification before utility hookups and enact other regulations relevant to responsible development.

This bill applies to counties subject to county regulations under Subchapter A or B of SB873. It applies to counties with a population of 150,000 or more and adjacent to an international border.

It also applies to counties with a population of 700,000 or more; or adjacent to a county with a population of 700,000 or more and within the same metropolitan statistical area as that adjacent county, as designated by the U.S. Office of Management and Budget.

The bill does not regulate the use of any building or property for business, industrial, residential or other purposes. Counties are not authorized to regulate the bulk height or number of buildings constructed on a particular tract of land. The bill excludes regulation of the size of a building that can be constructed on a particular tract of land, including without limitation and restriction on the ratio of building floor space to the land square footage. In addition, counties cannot regulate the number of residential units that can be built per acre of land.

Consultations within the Barton Springs Watershed

LCRA Pipeline - The Service issued a non-jeopardy biological opinion to the U.S. Army Corps of Engineers on October 13, 2000, on the effects of the LCRA pipeline, pump stations, and storage tanks on the salamander and golden-cheeked warbler. No take of the salamander was anticipated. The project is located in southwestern Travis and northern Hays Counties and will extend the availability of treated surface water. The LCRA committed not to provide water service to new development without the concurrence of the Service on water quality protection measures. Water service from the LCRA pipeline will not change impacts from existing development.

City of Austin and Texas Department of Transportation NPDES Permits - On August 28, 1998, the Service issued non-jeopardy biological opinions to EPA on proposed NPDES Municipal Separate Storm Sewer System permits for the City of Austin and Texas Department of Transportation - Austin District (TxDOT). The species in these opinions included the Barton Springs salamander, golden-cheeked warbler, black-capped vireo, Tooth Cave spider, Tooth Cave pseudoscorpion, Tooth Cave ground beetle, Kretschmarr Cave mold beetle, Bone Cave harvestman, and Bee Creek Cave harvestman. While development and traffic are expected to increase during the 5-year term of the permit, the monitoring component of the action should provide the data needed to develop a long-term program to reduce pollutant loading.

The City of Austin Municipal Separate Storm Sewer System permit applies to all areas, except agricultural lands, in the corporate limits of the City, served by or otherwise contributing to discharges from municipal separate storm sewers owned or operated by the City and to all areas, except agricultural lands, outside of that corporate boundary but within the jurisdiction of the City, served by or otherwise contributing to municipal separate storm sewers owned or operated by the City. The TxDOT Municipal Separate Storm Sewer System permit applies to all areas, except agricultural lands, in the corporate limits of the City of Austin, served by or otherwise contributing to discharges from municipal separate storm sewers owned or operated by the TxDOT and to all areas, except agricultural lands, outside of that corporate boundary but within the recharge zone of the Barton Springs Segment of the Edwards Aquifer served by or otherwise contributing to municipal separate storm sewers owned or operated by the TxDOT.

The permits require the City of Austin and TxDOT to implement a comprehensive Storm Water Management Program which includes pollution prevention measures, treatment or removal techniques, storm water monitoring, use of legal authority, and other appropriate means to control the quality of storm water discharge from the Municipal Separate Storm Sewer System to the maximum extent practicable.

City of Austin Habitat Conservation Plan - Impacts to water quality of the surface habitat were addressed, in part, in the Habitat Conservation Plan for Barton Springs (City of Austin 1998a). The Habitat Conservation Plan, which is part of the ESA section 10(a)(1)(B) permit issued to the City of Austin, substantially minimizes and/or mitigates take of salamanders from the operation and maintenance of Barton Springs Pool and the adjacent spring sites. The Habitat Conservation Plan is expected to improve salamander habitat, increase population size, and increase life history information over the term of the permit. The City of Austin and the Service have agreed to the following measures for the minimization/mitigation of incidental take of the salamander in the Habitat Conservation Plan: cleaning of the shallow end without lowering the entire pool; deepening an area of underwater habitat at northeast side of the pool); cleaning of the fissures, the new "beach" habitat, and adjacent springs using low-pressure hoses; maintenance of 11,000 square feet of "beach" habitat; removal of sediment and debris from the shallow end of the pool during cleaning; removal of silt and sediment in non-habitat areas of the deep end of the pool; modification of the gate system for the drawdown of the pool; modification of the bypass system to minimize the frequency of flooding in the pool; professional supervision and staff training; installation of a pump system to provide spring water for maintenance; retention of water over the fissures in the event of drawdown; surveys for stranded salamanders in the event of a drawdown for cleaning and maintenance; prohibition of the deliberate disturbance of substrate in the primary salamander habitat; restricted access to Eliza and Old Mill (Sunken Garden) springs; placement of thin limestone slabs over fissures in shallow section of fissures area; lowering of the main pool for cleaning only with Service concurrence; restoration of habitat of Eliza and Old Mill springs; reduction in surface water runoff into Barton, Eliza, and Old Mill springs; dedication of a portion of Barton Springs Pool revenue to conservation efforts; public education, scientific research for the salamander; and maintaining a captive-breeding program for the salamander.

Salamander Habitat Quality

In working together on this consultation, EPA and the Service agreed that EPA would provide a water quality assessment to the Service in support of the consultation. The Service has included excerpts from EPA's water quality assessment below. During the consultation process, EPA and the Service reviewed various conclusions regarding both the current state of water quality in the Barton Springs watershed and the projected conditions. We have relied on the available data sources which are STORET, USGS, City of Austin, and LCRA's draft Environmental Impact Study. LCRA's draft study encompasses the same geographical area as the action area affected by the CGP. The data sets evaluated by LCRA appear largely to be the same as is available for this consultation. Additionally, we considered information from the resources listed in Table 4 and the references listed at the end of this document.

The Barton Springs watershed consists of approximately 240,000 acres of contributing and recharge area (LCRA 2001). About 52,000 acres (21.7%) of the watershed have been converted to urban and suburban land uses. The following discussion of salamander habitat quality covers Barton Springs water quality, groundwater quality in the aquifer, surface water quality of the creeks in the watershed that provide recharge to the aquifer, and sediment quality in the springs and creeks of the watershed. Groundwater quality and surface water quality are included in the discussion because these areas contribute water and sediment to the surface habitat.

Water Quality

Water quality at Barton Springs is the result of a complex mix of land use patterns and natural processes within the watershed. Per the Barton Springs/Edwards Aquifer Conservation District (BS/EACD), aquifer hydrology of recharge and discharge is only beginning to be determined with any degree of accuracy and is likely to be more variable than previously considered (Hauwert et al. 1998, 2002). The following information is provided to explain the impacts to water quality within the Barton Springs watershed. It is difficult to quantify each of these threats in terms of impact to the salamander, its prey species, and/or its habitat quality. However, the factors which affect surface water quality and may lead to impacts on the Barton Springs salamander, its prey base, and habitat are:

Urban Expansion - The Austin area, including the Barton Springs watershed, is a fast-growing metropolitan area. Increases in human population may lead to increases in contaminant impacts, sewage effluent, transportation infrastructure, golf courses, and hazardous materials transportation.

Impervious Cover - The single most consistently useful indicator of watershed quality is overall impervious cover (Schueler 1994). "Profound and often irreversible impacts to the hydrology, morphology, water quality, habitat, and biodiversity of streams" can occur even at relatively low levels of impervious cover (Schueler 1994).

Riparian Buffers - A riparian area is the land area next to streams that provides shade, streambank stability, and filtration of upland runoff. Filtering is accomplished by making use of soil capacity, vegetation, and microorganisms to remove or break down pollutants (Mulamoottil et al. 1996). This relatively small proportion of the landscape is much more important to the proper hydrological and ecological functioning of ecosystems than its small size would indicate (Vannote et al. 1980, Gregory et al. 1991.)

Wastewater Systems - The primary sources of wastewater discharge to the environment that are of concern for the survival and recovery of the salamander are septic tank fields, organized sewage collection systems, and irrigation disposal of partially treated wastewater. Threats are present from direct impacts of bacteria and viruses, nutrient enriched algal blooms, discharge of oxygen demanding organic material, and concomitant discharge of toxic pollutants commonly found in domestic wastewater. In addition, any spills and leaks from sewer pipelines and lift stations may also add polluted water to the streams and aquifer system.

Water Quality Controls (Best Management Practices) - Water quality filters can remove 30 to 70 percent of most water-quality constituents if the filters are properly maintained (Glick et al. 1998). Best management practices mitigate pollutant loading but do not prevent water-quality degradation caused by urbanization (Glick et al. 1998). Maintenance of water quality treatment structures is also a long-term problem (City of Austin 1998b), and any lack of maintenance can further degrade environmental conditions.

Golf Courses - Golf courses contribute runoff that contains elevated levels of nutrients from fertilization. Pesticides, herbicides, and fungicides are also elevated in golf course runoff despite best efforts to manage the application of these chemicals (City of Austin 1997). Currently, six 18-hole golf courses (about 1,200 acres) are operated in the Barton Springs watershed. Elevated baseflow nutrient levels and algal blooms on the mainstem of Barton Creek have been observed to be concentrated in the immediate vicinity of golf courses using reclaimed wastewater (City of Austin 1997).

Transportation Infrastructure - Highways can have major impacts on groundwater quality (TNRCC 1994, Barrett et al. 1995). The TNRCC lists highways and roads as the fifth most common potential source of groundwater contamination in the Edwards Aquifer. Highway operation and maintenance increases concentrations of pollutants from vehicles and roadway runoff, which can be transported to sensitive areas such as Barton Springs. Increased traffic may translate into increased pollution loading.

Hazardous Materials Spills - Spills are an unpredictable, yet potentially significant source of pollutants for the Barton Springs watershed. The City of Austin's spill database, when regressed against impervious cover, indicates a strong empirical relationship between spill risk and impervious cover (City of Austin 1998b). Spill impacts are expected to increase as population density over the watershed increases due to: (1) a corresponding increase in the frequency of spills, (2) faster spill movement over impervious cover, and (3) expedited delivery to local creeks via storm sewer systems. Previous spills of hazardous materials have contributed to water quality degradation in watershed (City of Austin 1998b).

Water Quantity - Another threat to the salamander and its habitat is low flow conditions in the aquifer and at Barton Springs. Discharge at Barton Springs decreases as the aquifer water level drops, which historically has resulted primarily from a lack of recharging rains rather than groundwater withdrawal for public use. During drought conditions, spring flows can be reduced which could cause some negative effects on the salamander by restricting the amount of surface habitat available to the species. Increased demands for aquifer water can also reduce the quantity of water in the Barton Springs watershed. Groundwater pumpage has increased and its effects on aquifer levels and spring flows have become more pronounced during dry periods (Hauwert et al. 1998).

The City of Austin (2000) performed multiple linear regression analysis of long-term water quality data at Barton Springs, with spring flow and date as the independent variables. The size, percent, and direction of the change was calculated by comparing the medians, normalized to a flow of 50 cubic feet/second, of the earliest five-year period to the latest five-year period for which data was available (1975-1999). The City reported statistically significant trends for several chemical constituents and physical parameters. Conductivity, turbidity, sulfate, and total organic carbon show increases while the concentration of dissolved oxygen has decreased (Table 5). The significance and presence of trends are variable depending on flow conditions (baseflow vs. storm flow, recharge vs. non-recharge) and may be attributed to impacts from watershed urbanization (City of Austin 2000). The regression model R^2s ranged from 0.10 to 0.59. The R^2 value indicates how well the linear regression model correlating pollutant levels with time, will predict the future changes to pollutant levels due to time. The range of R^2 in linear regression analysis varies from 0 to 1, with values near 0 representing weakness in the relationship between pollutant levels over time and above 0.6 would generally indicate a stronger relationshipUsing the values of 0.10 to 0.59, the City of Austin concluded that these data indicated a long-term trend of water quality degradation at Barton Springs over the past 25 years.

Data collected by the City of Austin indicates that Upper Barton Springs may have lower water quality than Barton Springs Pool (Hauwert et al. 2002). While EPA's conclusions after examination of the available water quality data does not coincide with the City of Austin's determination, conditions at the upper springs may be related to higher levels of urbanization within the drainage area. The drainage area was identified in the draft City of Austin groundwater dye study as the Sunset Valley Route. The dye study indicates that stormwater runoff in the drainage area quickly recharges to groundwater, then discharges to Upper Barton Springs. The brief time between recharge and discharge at the springs suggests that aquifer attenuation does not significantly occur and degraded storm water may be released into Upper Barton Springs (City of Austin, presentations at the March 27, 2000, technical workshop on Barton Springs).

The Slade et al. (1986) study of ground and surface waters included water quality analyses for nutrients, bacteria, common inorganic constituents and selected trace elements, but did not include analysis for turbidity, dissolved oxygen, biochemical oxygen demand and suspended sediment in the ground water. The report uses EPA's drinking water standards to conclude that

"The quality of water in the Edwards aquifer generally is very good. Although relatively high concentrations for a few constituents have been detected at a few sites, no regional contamination problems have been identified by this water-quality sampling program." Slade et al. (1986) noted that fecal-coliform bacteria was the only constituent from Barton Springs that exceeded the standards. However, the report suggested that bacterial concentrations were lower in the aquifer than those in surface waters which recharge the aquifer because of attenuation during ground water transport. Slade et al. (1986) concluded that three samples taken from Barton Springs during the period from 1941 to 1955 showed nearly the same concentration of nitrate-nitrogen as the samples taken for the 1986 study (about 1.5 mg/l) and that they were relatively low.

However, studies of groundwater quality indicate that developed areas of the Barton Springs watershed are showing signs of degradation (Slade et al. 1986; City of Austin 1991a, 1991b, 1993; Hauwert and Vickers 1994; Texas Groundwater Protection Committee 1995). In a water quality study done in the Barton Springs watershed, Slade et al. (1986) reported levels of fecal-group bacteria, nitrate nitrogen, and turbidity highest in wells near creeks draining developed areas. Total nitrogen (as nitrogen) concentrations measured in wells in the more urbanized areas of the Barton Springs watershed were typically two to six times higher than in rural areas (Slade 1992). The BS/EACD has documented levels, elevated above background, for of sediment, fecal-group bacteria, heavy metals, nutrients, and petroleum hydrocarbons in springs and wells in urban areas (Hauwert and Vickers 1994, Texas Groundwater Protection Committee 1995). Nutrients such as nitrate promote eutrophication of aquatic ecosystems with lowered oxygen levels and growth of bacteria, algae, and nuisance aquatic plants (Menzer and Nelson 1980).

Groundwater quality at Barton Springs can be influenced by recharge from a large land area. The Barton Springs segment of the Edwards aquifer is about 20 miles long, with a recharge zone that covers an area of about 90 square miles. The upstream contributing zone, which contains streams that flow onto and discharge into the aquifer, covers 264 miles (Scanlon 2000). Recharge for other springs in this segment occupy a small part of the recharge and contributing zone. Recent tracer tests confirm a large source area for Barton Springs (Hauwert et al. 2002).

Draft City of Austin groundwater tracing studies (Hauwert et al. 2002) suggest the existence of three distinct groundwater flow-paths that lead to Barton Springs. The Sunset Valley Flow Route appears to be the main contribution of groundwater to Upper Barton Springs. The Sunset Valley groundwater basin recharge is believed to generally include recharge areas of Kitchen Branch of Williamson Creek, the main branch of Williamson Creek below Mopac Expressway, and Barton Creek below Loop 360. This basin, supplying Upper Barton Springs and a part of Main Barton Springs, is 11.7 square miles in size (Hauwert et al. 2002). According to the dye trace study, recharge waters move quickly along the flow route and are evident at the Upper Barton Springs in as little as 30 hours during high flows to as long as three days under low flows. In addition, the dye continued to be detectable at lower concentrations for several months after the initial detections (Hauwert et al. 1998, 2002).

The dye tracing study further concludes that the primary source area for Main, Eliza, and Old Mill springs includes recharge areas of the Slaughter, Bear, Little Bear, and Onion Creek watersheds. Recharged groundwater from these watersheds appears to flow along the Manchaca Groundwater Flow Route from the watersheds to the springs and appear to travel in pathways taking 2 to 28 days from recharge to sighting at the springs. The dye study indicated that recharge within four miles of the springs appears relatively quickly in the springs, usually within 10 to 30 hours. The area within a two-mile radius of the springs appears largely developed, although the undeveloped part of Zilker Park encompasses roughly a one square mile area with the springs outlets located at the north boundary.

A major potential threat to water quality in the aquifer and at Barton Springs is associated with changes in land use that degrade the quality of storm water runoff. Surface water quality affects stream water quality and is a factor that can be most easily controlled. Direct surface runoff carries contaminants and other toxic materials that have been washed off the land surface. Surface water quality can vary substantially among areas with different land uses. Nonpoint sources (e.g., storm water runoff) and point source contamination (e.g., municipal treatment facilities) can alter the surface water quality in the watershed. Nonpoint sources of contaminants are heavily influenced by the location, amount, and type of impervious cover (Schueler 1987).

The quality of water in the Edwards aquifer is a result of several factors including quality of the water which recharges the aquifer, processes within the aquifer, and, in some areas, the influence of leakage from underlying aquifers or lateral flow within the aquifer (Slade et al. 1986). Slade et al. (1986) cites dilution, sedimentation, absorption, adsorption, chemical precipitation, and die-off of microorganisms as active processes affecting ground water as it moves through the aquifer. It is probable that discharge from the springs of local origin is changed minimally in its chemical, physical, and biological qualities. Water recharged from features further from the springs outlet appear to take longer to move underground to the springs and therefore may be attenuated by the aquifer during the journey.

Recharge through the stream channels generally occurs through large openings where there is no mediating effects of a soil cover. Slade et al. (1986) suggested that about 85% of the total aquifer recharge in the Barton Springs Segment of the Edwards Aquifer enters the aquifer through faults and fractures along the main channels of six creeks that cross the recharge area (Table 6). The remaining 15% occurs in the areas between the main channels by infiltration of precipitation (Slade et al. 1986).

Recharging water in Barton Creek can emerge in any of the spring sites inhabited by the salamander (N. Hauwert, City of Austin, pers. comm. 2002). In addition, surface flow can directly effect salamander habitat at Barton Springs Pool, Upper Barton Springs, and in Barton Creek below Old Mill Spring.

Specific conductance, related to the concentration of dissolved solids, are lower at Barton Springs during high flows and increase to background levels as the spring flow declines (Slade et al. 1986). Recharge water moving through the aquifer dissolves calcium carbonate and other soluble minerals in the rocks of the aquifer, resulting in increased specific conductance and dissolved solids. Base flows, which have longer residence times in the aquifer, contain higher concentrations of these dissolved substances than the storm water flows. The highest nitrate and bacteria levels have generally been found in the recharge area, in wells near creeks. "Runoff probably transports these constituents from source areas of animal and human feces to the creeks where it enters the aquifer with recharge water." (Slade et al. 1986).

Turbidity of Barton Springs water is strongly related to turbidity in Barton Creek which provides 28% of the spring flow and moves rapidly from recharge points to the spring. According to Slade et al. (1986), high turbidity at the springs in 1980 corresponded to a greater amount of construction activity in the watershed than during the sample periods of 1981 and 1982 when construction activity had declined and spring samples showed lower turbidity. The transport of sediments and a number of other pollutants from surface runoff which recharges the aquifer occurs predominantly during storm events.

In 2000, the USGS sampled Barton Springs Pool, Eliza Spring, Barton Creek, and Williamson Creek for soluble pesticides both during and after a two-day storm event (USGS 2000). Positive detections of four pesticides (atrazine, carbaryl, diazinon, and simazine) were documented at both Barton Springs Pool and Eliza Spring. Atrazine and simazine are used as herbicides while carbaryl and diazinon are insecticides. Peak concentrations of the four pesticides detected at the two springs were 0.56 µg/l for atrazine, 0.013 µg/l for carbaryl, 0.028 µg/l for diazinon, and 0.011 µg/l for simazine. Deethylatrazine, a residue of atrazine, was also detected with a peak concentration of 0.033 µg/l. The USGS (2000) water quality sampling included surface water samples from Barton Creek and Williamson Creek. Peak concentrations of three pesticides detected during the 2-day storm event were 0.80 µg/l for atrazine, 0.47 µg/l for carbaryl, and 0.26 µg/l for diazinon. The peak concentration for the deethylatrazine residue of atrazine was 0.03 µg/l.

The peak carbaryl concentration in the USGS (2000) study at Barton Creek and Williamson Creek approaches chronic criteria for concentrations of non-persistent toxic materials as determined by the Texas Surface Water Quality Standards (TNRCC 1997). To calculate chronic criteria for water quality, the Texas Surface Water Quality Standards uses a factor of 0.1 of the LC_{50} from the most sensitive aquatic organism. Using a 48 hr. LC_{50} of 6.4 µg/l (using ASTM water) for waterflea *(Daphnia pulex)* from Mayer and Ellersieck (1986), the calculated criteria value for carbaryl chronic toxicity is 0.64 µg/l (vs. 0.47 µg/l in the USGS water quality sampling).

Diazinon is a commonly used pesticide in commercial and residential areas which may remain biologically active in soils for up to 6 months under conditions of low temperature, low moisture, high alkalinity, and lack of microbial degraders (Eisler 1986). Diazinon can cause adverse effects in aquatic invertebrates at concentrations of 0.30 µg/l including inhibited reproduction, impaired feeding, and increased mortality of aquatic invertebrates such as amphipods, mayflies, caddisflies, and damselflies (Eisler 1986). To adequately protect sensitive aquatic fauna, Eisler (1986) suggested that diazinon in water not exceed 0.08 µg/l. The reported level for diazinon of 0.26 µg/l in Williamson Creek (USGS 2000) exceeds Eisler's (1986) suggested level for the protection of sensitive aquatic fauna by threefold. Hauwert (et al. 2002) dye tracing studies indicate that water from Williamson Creek can reach Barton Springs in less than 30 hours with very little attenuation or dilution.

Recent data on acute toxicity of diazinon to adult Barton Springs salamanders (in water hardness of 286 mg/l as calcium carbonate) indicates that the 96 hour 50% mortality (LC_{50}) is above 343 µg/l (Jim Dwyer, Service, unpublished data). Acute diazinon toxicity to larvae of the salamander is not known. Harris et al. (1998) reported median concentrations of diazinon causing 50% mortality (16 day LC_{50}) to larvae of green frogs (*Rana clamitans)* of 2.8 µg/l to 5 µg/l, which is two orders of magnitude higher than concentrations measured at Barton Springs. This suggests that diazinon is not acutely toxic to the salamander at current ambient levels. However, the study did note that frequent exposure to concentrations between 0.04 and 1.04 µg/l could seriously impact the development and survival of the green frog early life stages (Harris et al. 1998). Since chronic effects of diazinon on the salamander and evaluation of sublethal endpoints have not been studied, sublethal impacts on salamander development and survival could occur at lower concentrations.

The USGS sampled for soluble pesticides in Barton Springs and in Barton Creek following a rain event in May 2001. Atrazine, carbaryl, metolachlor, prometon, diazinon, and simazine were documented at Barton Springs. Carbaryl, diazinon, and simazine at the springs were found at levels below exhibited toxicity to aquatic animals. Although concentrations of these pesticides are below aquatic life criteria set in the Texas Surface Water Quality Standards, increases in pesticide concentrations could adversely affect aquatic organisms.

A peak concentration of 3.19 µg/l of atrazine was detected at Upper Barton Spring. The atrazine was still present at about 0.50 µg/l four days after the storm. This study indicates that different chemicals are reaching the spring sites at different times, indicating different watershed sources. Chemicals in storm water runoff from farther out in the watershed may reach the springs later but have longer residency times. These sources that appear to be farther out in the watershed also have more time for dilution or attenuation of pollutant concentrations.

Hayes et al. (2002) studied the sublethal effects of atrazine on sexual development in frogs, finding that atrazine produced hermaphrodites at concentrations $\geq$ 0.1 µg/l, and caused reduction in male laryngeal size at concentrations $\geq$ 1.0 µg/l. Peak concentrations of atrazine detected at Barton Springs during May 2000 were more than 5 times greater than concentrations found to produce gonadal abnormalities and hermaphroditism in African clawed frogs (*Xenopus laevis*). One year later (May 2001), peak concentrations were over an order of magnitude higher (3.19 µg/l) than concentrations found by Hayes et al., to cause disruption of sexual development in frogs.

Sediment

Mobile sediments in karst are potential vectors for the transport of hydrophobic contaminants (Mahler et al. 1999). Sediments may have a direct impact on habitat quality and can act as a transport mechanism for other contaminants (Menzer and Nelson 1980). Karst systems are more vulnerable to the effects of pollution because of their thin surface soils, high groundwater flow velocities, and the relatively short time that water is resident within the system (Ford and Williams 1994) Surface-derived sediment in particular which may be exposed to contaminants at the surface and can have a relatively high organic carbon content, may be a significant source of groundwater contamination. (Mahler and Lynch 1999).

Sediment from soil erosion is the carrier of many pollutants found in water and has been cited as the greatest single pollutant of surface waters by volume (Menzer and Nelson 1980). Uncontrolled construction activities can generate large amounts of sediment that greatly exceed natural erosion rates. During construction activities, disturbed soil is easily eroded and carried off by runoff during storm events, unless best management practices are followed. Alteration of soil cover, drainage patterns, and the physical characteristics of the soil itself during construction and landscaping also increase sediment concentrations in storm water discharge from developed sites (Virginia Department of Conservation and Recreation 1992).

Turbidity, the reduction of clarity in water due to the presence of suspended or colloidal particles, is comprised in surface water of several naturally occurring or introduced organic matter and inorganic minerals. High levels of turbidity can disrupt behavioral and cellular processes in aquatic organisms by impairing the organism's ability to locate food resources or potential mates and avoid predators (EPA 1986, Schueler 1987). Suspended sediments can impact respiratory processes by direct smothering or clogging of gill structures (Garton 1977, Werner 1983; Schueler 1987). Sediment build-up in source areas can also block recharge that could otherwise enter into sinkholes, caves, and other recharge features (EPA 1986, Schueler 1987), and could consequently influence water quantity at Barton Springs.

Areas of high quality salamander habitat, principally composed of cobble and healthy aquatic macrophytes, have decreased in recent years due to the deposition of silt and sediment (City of Austin 1998a). Sediment build up in salamander habitat appears to have increased in the last 10 years. Prior to the early 1990s, Barton Springs (including Main, Eliza, and Old Mill Springs) had abundant course gravel, cobble, and healthy plants with very little sediment accumulation (D. Hillis, University of Texas, pers. comm. 2002). There is currently a 2- to 4-inch accumulation of sediment that covers all available habitat at Eliza Spring (City of Austin, unpublished data). Similarity, Old Mill Spring and Upper Barton Spring are now impacted by sediment accumulations (City of Austin 1998a).

Some studies have indicated that species in or near contaminated sediments may be adversely affected even if water quality criteria are not exceeded (Landrum and Robbins 1990, Medine and McCutcheon 1989). Sediments can act as a sink for many organic and inorganic contaminants (Menzer and Nelson 1980, Landrum and Robbins 1990, Medine and McCutcheon 1989) and can accumulate these contaminants to levels that impact aquatic ecosystems (Landrum and Robbins 1990, Medine and McCutcheon 1989). Sediment samples were taken from the bottom of Barton Springs and Barton Creek during normal flow periods and from storm flow of the springs and the creek during periods of heavy precipitation.

Barton Springs Sediment Data - Sediment sampling data for Barton Springs provided by the City of Austin included results for 201 different parameters resulting in a total of 2,950 sample results being reported. Of the 2,950 sample results reported, 2,397 values were reported as non-detects and 553 values were reported as detects. Of the 201 parameters analyzed, 46 different parameters were reported with at least one measurable result. The 46 parameters included results for both chemical and physical properties.

Eleven of the sediment samples collected by the City of Austin from Barton Springs Pool (between April 1995 and February 2001) were analyzed for PAHs, pesticides/herbicides, and metals. Of 99 reports, metals were detected 33 times. Repeated detections are noted for the metals arsenic (3 of 11 samplings), cadmium, (3 of 11 samplings), copper (6 of 11 samplings) and silver (2 of 11 samplings). The eleven samples were tested for twelve individual PAH congeners, yielding 132 reports on PAHs. Total PAHs were reported by adding the detected levels of each congener together for each sampling event. Thirty-eight of the 132 results were detectable. No pesticides, herbicides, or PCBs were reported at detectable levels. The results of the sampling for metals and PAHs are found at Table 2.

The USGS has collected (5/2000 - 11/2000) and analyzed four grab samples also of bottom sediment from the Barton Springs Pool. Metals results are shown in Table 3. PAH results are listed in Table 4. Samples were evaluated for levels of eight different metals. Of the 32 results, all were measured at detectable levels. Of note, silver, chromium, copper, and nickel were measured at detectable levels in each of the four samples. USGS also sampled bottom sediments six different times between 5/99 and 11/00 and tested for PAHs. Results are given for both Total PAHs as well as nine PAH congeners. Fifty of the fifty-four results reported PAHs at detectable levels.

Barton Creek Data - Between 11/94 and 7/00, the City of Austin collected and analyzed eleven grab samples of bottom sediments of Barton Creek, within 1/4 mile of the Barton Springs Pool. Results of testing these samples for eight metals, twelve individual PAH congeners, and ten pesticides are found in Table 7. Total PAHs in Table 7 are calculated as the addition of the detectable levels of each of the twelve congeners found in each sampling event. Forty-nine of eighty-eight tests for metals yielded detectable levels. Detectable amounts of zinc were found in each sample. Seven of 11 samples found detectable levels of PAHs. Of the 11 samples, 9 had at least one metal exceed comparison criteria. Sixty-four of 132 results report detectable levels of PAH. One of the eleven samples found detectable levels of pesticides. Those pesticides identified and the results are shown in Table 7.

Data from the City of Austin for sampling done at locations in the mainstem of Barton Creek greater than 1/4 mile from the Barton Springs Pool between 5/94 and 9/00 is shown in Table 6. Testing the eleven samples for metals yielded 64 detects out of 99 reports with detectable levels of metals found in each sample. Most commonly detected was Zinc, found at detectable levels in each of the eleven samples. Of the thirteen PAH congeners tested for, only five were found at detectable levels. Eight of 142 test results found PAHs at detectable levels.

Suspended Solids - In the USGS sediment study (Tables 8-10), suspended sediment was collected from the streamflow or springflow during storm events when the streams had high levels of turbidity. For these samples, the storm water was filtered to concentrate sufficient sediment to allow for chemical testing. These samples represent the sediment concentration being discharged at the springs and carried in the streamflow of Barton Creek. These suspended sediments likely, in part, contribute to the bottom sediments that eventually settle out in salamander habitat.

Assessments of sediment quality commonly include analyses of anthropogenic contaminants, benthic community structure, physicochemical characteristics and direct measures of whole sediment and pore water toxicity. Accurate assessment of environmental hazard posed by sediment contamination depends in large part on the accuracy and representativeness of these analyses.

Data are presented in Tables (2-7) comparing concentrations of contaminants found in the action area to proposed sediment quality screening guidelines. The sediment screening guidelines used for comparison in each table are taken from three proposed approaches (TNRCC 2000, EPA 1997, MacDonald et al. 2000). The three approaches are presented here for purposes of comparison of possible adverse effects of sediment contaminants on salamanders and their habitat

TNRCC (2000) has proposed ecological screening benchmarks for sediment contaminants in Guidance for Conducting Ecological Risk Assessments at Remediation Sites in Texas. These benchmarks are intended to be conservatively protective of aquatic life and are focused on benthic macro invertebrates (e.g., salamander prey species). Levels that exceed these benchmarks at contaminated sites would require further investigation because of the potential for adverse effects to aquatic life.

MacDonald et al. (2000) proposed "consensus based" sediment quality guidelines based on a nationwide database with sediment studies that have been conducted for contaminant levels of concern and levels that have been documented to cause impacts when exceeded. MacDonald et al. (2000) identified the TEC as the concentration in sediment below which adverse effects would not be expected to occur. These TECs can be used to predict the presence or absence and frequency of sediment toxicity in field-collected sediments (MacDonald et al. 2000).

EPA (1997) has proposed screening values for sediment concentrations for chemicals as evaluated in their national sediment quality survey. The Threshold Effect Level (TEL) sets concentrations below which adverse effects are not expected to occur. The Probable Effects Level (PEL) sets concentrations above which adverse effects are expected to occur. The PEL is a concentration which is likely to cause adverse biological effects and habitat degradation when exceeded. The PELs represent contaminant levels, that when exceeded, probably result in adverse biological effects to aquatic organisms. The observed effects include impaired growth, reduced survival, and direct mortality.

Storm flow that carries sediment through to the aquifer and into salamander habitat can also transported sediments that have been contaminated with toxic pollutants such as pesticides, PAHs, and heavy metals. Adverse effects to the salamander could include impaired growth, reduced survival, reduced prey density, reduced prey quality, altered behavior, morphological and developmental aberrations, reduced reproductive success, and direct mortality.

EPA has informed the service that available data for sediment characterization is limited and has not been subject to quality analysis by EPA. Data may unintentionally be biased by a variety of factors, including method of sampling (grab vs. composite), frequency (seasonal, even, duration of exposure determination), and other physical limitations (varied depths of sediment sample affect ability to correlate results, conditions and duration, sample storage method). Reflected in the data, as presented, are levels of pollutants which potentially may affect the salamander primarily through its food chain. Because factors other than chemical composition may alter effects at any given site, further site-specific testing is recommended when PELs are exceeded in sediments. The insufficiency and quality of data to characterize sediments is being addressed as part of the terms and conditions of this consultation.

Heavy Metals in Sediments

Heavy metals attached to sediment may have toxic effects on the prey species at the springs (Ingersoll et al. 1996) and could have toxic effects on the salamander.

In bottom sediments at Barton Springs (Table 2), six heavy metals exceeded at least one sediment screening criterion on 170 occasions out of 99 results reported (33 results were detected.) At least one criterion for arsenic was exceeded on 4 occasions; cadmium on 3 occasions; copper on 6 occasions; mercury and nickel on 1 occasion; and silver on 2 occasions. Copper and silver PELs were each exceeded on 2 occasions. Copper concentration was almost 5 times PELs on one occasion. Silver concentration was over 50 times PELs on one occasion.

Eleven samples collected by the City of Austin (Table 7) at sites within 1/4 mile of the Barton Springs Pool found 10 test results exceeding sediment quality criteria in 88 reports (49 results detected). Cadmium exceeded sediment quality criteria in five of the seven samples where detectable amounts were measured. Silver exceeded sediment quality criteria in both of the two samples where it was detected. Copper and lead each reported one result exceedance of sediment quality criteria out of ten detectable results. No value exceeded PEL.

USGS sampled suspended sediments in creek flow at Barton Creek just above Barton Springs on five dates during storm events, primarily calendar year 2000, and tested for eight metals. Of the forty results, all but one were measured at detectable levels. Silver exceeded sediment guideline criteria once and cadmium in three of the five sampling events. Arsenic, chromium, copper, nickel, lead and zinc exceeded sediment quality criteria in each sample. Zinc exceeded PEL once in five samples.

In Barton Creek upstream of Barton Springs Pool (Table 6), sampling by the City of Austin resulted in four metals - arsenic, cadmium, lead, and silver, detected at levels above sediment quality guidelines in nine of eleven samples. Arsenic exceeds guidelines in 5 of 11 samples, silver in three of 11 samples, cadmium and silver each exceed criteria only once out of 11 samples. Data shows only ten samples exceeded criteria out of 99 tests (64 detectable amounts). Three samples out of the eleven showed levels above the PEL for a metal.

Grab samples of suspended sediments in creek flow at Barton Creek at Highway 71 were collected by USGS during four storm events in 1999 and 2000. Thirty-nine tests of forty tests identified detectable levels of eight metals. Fifteen samples exceeded at least one sediment quality guideline. Only one of the fifteen results, one test for Zinc, exceeded the PEL.

<u>Polyaromatic Hydrocarbons in Sediments</u>

In bottom sediments at Barton Springs, collected by the City of Austin (Table 2), all but one result of the 56 detected of 132 results, exceeded at least one of the sediment quality guidelines. . Of the twelve PAH congeners tested for, six individual PAHs have exceeded PELs on a total of 30 occasions (38 detects of 132 results). In addition, low molecular weight PAHs exceeded PELs on 3 occasions, while high molecular weight PAHs have exceeded PELs on 5 occasions. Five PAHs were more than 5 times PELs on 14 occasions.

Sediments collected from Barton Springs also contained PAHs at levels up to 6.5 times those shown to be toxic to *Hyalella azteca* (Ingersoll et al. 1996, City of Austin 1998b). USGS collected samples of suspended sediments from the springs discharge at Barton Springs Pool during storm events, six separate sampling events, primarily during calendar year 2000. Testing found detectable levels of PAHs in 47 of 60 samples but did not detect Total PAHs nor individual congeners at levels exceeding any sediment quality guidelines.

Each of the eleven grab sediment samples collected from creek bottom sites by the City of Austin within 0.25 miles of Barton Springs Pool (Table 7) were found to have levels of PAHs exceeding at least one sediment quality guideline. Of these creek samples, total PAHs exceeded at least one criteria for 7 of the 11 samples. Fifty-nine tests showed levels of PAHs exceeding one of the sediment quality guidelines. Fifty-two of the 143 tests (71 detects) for PAH exceed PELs. of the PAHs collected were 2.5 to 22 times the levels shown to have a toxic effect (survival, growth, or maturation) on the amphipod *Hyalella azteca* (Ingersoll et al. 1996, City of Austin 1998b), a known prey item for the salamander.

USGS collected samples of suspended sediments from Barton Creek flow above Barton Springs during storm events, five separate sampling events, primarily during calendar year 2000 (Table 3). Testing found detectable levels of PAHs in 47 of 50 samples and 40 samples exceeded sediment screening guidelines. Total PAHs test results, as well as results for phenanthrene, anthracene, flouranthene, pyrene, benzo(a)-anthracene, chrysene, and benzo-(a)pyrene, exceeded sediment screening criteria at each sampling event.

Eleven grab sediment samples were collected from Barton Creek at sites along the mainstem upstream of the pool (>0.25 miles) between May 1994 and July 2000 (Table 6). Only 7 of 154 tests for PAH congeners and Total PAHs were measured above any of the screening guidelines. . Total PAHs for these sites were less prevalent with 18% of samples having concentrations greater than the sediment criteria. Sediments collected from the mainstem of Barton Creek in 1994 contained several PAHs that were 2.5 to 22 times the levels shown to have a toxic effect (survival, growth, or maturation) on the amphipod *Hyalella azteca* (Ingersoll et al. 1996, City of Austin 1998b), a known prey item for the salamander.

USGS collected samples of suspended sediments from Barton Creek flow at Highway 71during storm events, four separate sampling events, primarily during calendar year 2000. The testing found detectable levels of PAHs in 47 of 54 samples, and found two levels of benzo-(a)pyrene exceeding sediment screening guidelines. Samples for eight other PAH congeners and Total PAHs did not exceed sediment screening guidelines.

Pesticides in the Sediments

Several pesticides have been documented in sediments in Barton Creek (City of Austin 1997). Pesticides documented include aldrin; 1,1-dichloro-2,2-bis(p-chlorophenyl) ethane (DDD); 1,1-dichloro-2,2-bis(p-chlorophenyl) ethylene (DDE); 1,1,1-trichloro-2,2-bis(p-chlorophenyl)ethane (DDT); delta-BHC; endosulfan I; endrin; gamma-BHC; heptachlor epoxide (a metabolite of heptachlor); heptachlor; and lindane (City of Austin 1997). Although most of these pesticides are no longer in use, their presence is cause for concern as some of these pesticides may adversely affect the salamander's prey base or the salamander itself at sufficient concentration. Their presence is also a concern from the stand point of synergistic effects to the salamander and its prey base.

Pesticide data from the suspended sediments in Barton Creek flow during storm events exceeded sediment quality guidelines on 6 occasions (Table 5). Both of the two results for DDE from 5 separate sampling events exceeded sediment quality guidelines. Chlordane concentrations in four of four separate sampling events of Barton Creek flow during storm events exceeded the PEL on all occasions at Highway 71 and on one occasion above Barton Springs. Concentrations at Highway 71 were more than 20 times PELs on one occasion, and concentrations just above Barton Springs were more than 10 times PELs.

Concentrations of 9 pesticides exceeded sediment screening criteria a total of 10 times (Table 7). Five exceeded PELs a total of 6 times. Detections of pesticides were found in each of the 10 times it was measured. An 11/94 sampling event found exceedences of the PELs for P,P'-DDD , P,P'-DDT, Delta-BHC, and Lindane. Only one data point for each parameter is given with the exception of Beta-BHC which registered two measurements above the PEL for samples collected in 1997. One measurement for P,P'-DDD was almost 100 times the PELs, and values for delta-BHC were more than 50 times PELs. Concentrations of endrin, a highly toxic contaminant, were found at more than 200 times effects criteria. .

Several pesticides have been documented in sediments in Barton Creek (City of Austin 1997). Pesticides documented include aldrin; 1,1-dichloro-2,2-bis(p-chlorophenyl) ethane (DDD); 1,1-dichloro-2,2-bis(p-chlorophenyl) ethylene (DDE); 1,1,1-trichloro-2,2-bis(p-chlorophenyl)ethane (DDT); delta-BHC; endosulfan I; endrin; gamma-BHC; heptachlor epoxide (a metabolite of heptachlor); heptachlor; and lindane (City of Austin 1997). Although most of these pesticides are no longer in use, their presence is cause for concern as some of these pesticides may adversely affect the salamander's prey base or the salamander itself at sufficient concentration. There presence is also a concern from the stand point of synergistic effects to the salamander and its prey base.

Pesticide data from the sediments in Barton Creek exceeded sediment quality criteria on 6 occasions (Table 10). Concentrations of DDE exceeded effects criteria above Barton Springs on 2 occasions. Chlordane concentrations exceeded the Possible Effects Level on all occasions at Highway 71 and on one occasion above Barton Springs. Concentrations at Highway 71 were more than 20 times Possible Effects Levels on one occasion, and concentrations just above Barton Springs were more than10 times Possible Effects Levels.

Concentrations of 10 pesticides exceeded sediment screening criteria a total of 11 times (Table 12). Five exceeded Possible Effects Levels a total of 6 times. One measurement for P,P'-DDD was almost 100 times the Possible Effects Levels, and values for delta-BHC were more than 50 times Possible Effects Levels. Concentrations of endrin were found at more than 200 times effects criteria. Chlordane contamination measured in high concentrations is also likely to impact aquatic life. This data is somewhat puzzling as these compounds should not go from very high levels to very low levels in a short time as the raw data shows.

The quality of surface water in Barton Springs is intricately linked to the quality of ground water within the Edwards Aquifer. Estimates as high as 85% of the total aquifer recharge in the Barton Springs Segment of the Edwards Aquifer enters through faults and fractures along the main channels of six creeks that cross the recharge area. The remaining 15% occurs in the areas between the main channels by infiltration of precipitation. Water supporting Upper Barton Springs and a portion of Barton Springs Pool is believed to come from areas of recharge along the Kitchen Branch of Williamson Creek, the main branch of Williamson Creek below Mopac Expressway, and Barton Creek below Loop 360. Water supporting Barton Springs Pool, Eliza, and Old Mill springs is believed to come from recharge areas within the Slaughter, Bear, Little Bear, and Onion Creek watersheds (Hauwert et al. 2002).

It is generally accepted that profound and often irreversible impacts to the hydrology, morphology, water quality, habitat, and biodiversity of streams can occur within a watershed due to urbanization through construction and the replacement of soils with impervious cover. A major threat to the water quality of the Edwards Aquifer and Barton Springs is associated with changes in land use that degrade the quality of storm water runoff. As urbanization and other development has occurred within the watershed, the quality of the Edwards Aquifer water has shown signs of degradation by fecal-group bacteria, nutrients, heavy metals, petroleum hydrocarbons, sediment, and turbidity. The City of Austin (2000), concluded that measures of water quality in Barton Springs, such as the conductivity, turbidity, sulfate content, and total organic carbon have statistically significant increases while the concentration of dissolved oxygen has decreased significantly over the past 25 years. In addition, the City of Austin (2000) concluded that some of these trends could be attributed to impacts from watershed urbanization. The transport of sediments and a number of other pollutants from surface runoff which recharges the aquifer occurs predominantly during storm events.

Direct surface runoff carries sediment, contaminants, and other toxic materials that have been washed off the land surface. Activities that disrupt the integrity of the land surface have identifiable impacts to water quality. For example, high turbidity found at the Barton Springs in 1980 corresponded to a greater amount of turbidity in Barton Creek with corresponded to a greater amount of construction activity in the watershed. Storm flow that carries sediment through to the aquifer and into salamander habitat has also transported sediments that have been contaminated with toxic pollutants such as pesticides, PAHs, and heavy metals. Copper, silver, and PAHs were found in concentrations in sediments to exceed Possible Effects Levels reported by EPA (1997) and others to be a concentration which is likely to cause adverse biological effects and habitat degradation when exceeded over time. Sediments have been contaminated to the extent that adverse effects to the salamander, its prey, or habitat quality might be likely. Adverse effects to the salamander could include would at this time most likely include those caused by the physical impact of sedimentation and reduced prey density and quality. The incidence of sediment with contaminants exceeding protective sediment quality criteria suggest that there may be a reduction in the quality of salamander habitat.

IV. Effects of the Action

The constant flow of water and relatively constant temperature at Barton Springs provide habitat conditions that are suitable for salamander reproduction year-round. All life stages of the salamander and its prey are present at Barton Springs at all times. Possible adverse effects to the salamander from the proposed action involve the pathways and delivery of pollutants through the aquifer and stream system to salamander habitat. The timing, nature, and duration of the effects are not well documented. The timing for delivery of pollutants to salamander habitat will be related to storm events within the watershed. Watershed hydrology (rainfall, runoff, and delivery to the aquifer, etc.) and sediment transport through the aquifer system will drive the delivery of pollutants to Barton Springs. Although the temporal and spacial distribution of this data does not allow one to make a firm conclusion about possible effects to the salamander from all sources or the action under consultation, the Service is concerned about the possible additive and synergistic effects, the physical impacts of sedimentation, and the possible impacts to the salamander's prey base.

There are no direct effects from construction activities because none of the construction will discharge directly into Barton Springs. There are two types of indirect effects to the salamander, those that occur during construction and those that occur post-construction.

Effects During Construction

Leaks and spills from construction equipment and materials storage areas may occur. In general, such spills are relatively small and the CGP contains provisions to minimize the adverse effects of these spills. Small amounts of these contaminants may reach the streams and impact the water quality at Barton Springs. Any potential impact to the salamander is anticipated to be relatively minor.

Estimates of acres to be disturbed in the course of development over the remaining life of the CGP are difficult to project with accuracy. EPA referred to its storm water NOI database to estimate acreage but found the data to be unreliable for this purpose. Therefore, EPA has relied upon other estimates (Table 14). The Service estimated between 2,000 and 5,000 acres of construction would occur during the last two years of the CGP (1,000-2,500 acres per year). TxCABA (2002) estimated less than 530 acres of new residential construction, plus an additional 10 to 15% (53-80 acres) of commercial construction. EPA estimated 2,051 acres (approximately 1,641 acres per year), based on LCRA data, would be disturbed through July 2003.

EPA estimated TSS annual loads due to runoff from construction activity in the Barton Springs watershed. The EPA's projected loading estimates for projects covered by the CGP take into effect local controls that will govern building in the watershed. Average impervious cover, based on past records was used, and required controls, based on applicable local ordinances was considered in the calculations. EPA calculated that TSS pollutant loads from CGP compliant construction sites will be about 983,833 pounds. Based on the available data, the construction phase pollutant loads from construction sites that are compliant with the CGP's terms and conditions will account for 0.05% of the surface water TSS loads in the watershed for the life of the permit. Some portion of the sediments that are mobilized during storms may reach Barton Springs either by surface flow (flooding of Barton Creek into the springs) or groundwater flow through the aquifer, with the largest proportion remaining in surface water discharging into Town Lake. The amount of sediment deposition at the springs is dependent of the magnitude and rate of the storm event, soil conditions, creek flow, groundwater transport, and the volume of spring discharge.

Some of the potential salamander habitat at all four spring sites is unsuitable due to sediment deposition. Sediment deposition will continue to impact suitable habitat by decreasing its quality and may reduce the amount of suitable habitat available. Increased levels of TSS and sediment deposition in the springs may also have deleterious effects on the salamanders' physiology and proper development of their eggs and larvae.

In addition to covering salamander habitat, problems resulting from increased sediment loads include: clogged gills of aquatic species, causing asphyxiation (Garton 1977, Werner 1983, Schueler 1987); smothered eggs and reduced availability of spawning sites (EPA 1986, Schueler 1987); filling of interstitial spaces and voids, reducing water circulation and oxygen availability (EPA 1986); filling and blocking recharge features and underground conduits, restricting recharge and groundwater storage volume and movement; reducing light transmission needed for photosynthesis, food production, and the capture of prey by sight-feeding predators (EPA 1986, Schueler 1987); and exposing aquatic life to contaminants that readily bind to sediments (such as petroleum hydrocarbons and heavy metals).

Sediments currently cover much of the bottom of Barton Springs Pool, Eliza Spring, Old Mill Spring, and Upper Barton Springs. This is a major change from historic accounts of these springs that had crystal clear conditions with little silt or sediment (City of Austin 1998a). Salamanders are typically found in silt-free areas, where sheltering habitat and food are abundant. Although most of the loading delivered to the stream system from sources throughout the watershed would not be expected to reach the Barton Springs, some fraction of the TSS load could potentially be an additional sediment load at Barton Springs.

Post-Construction Effects

EPA estimated the following average post-construction pollutant loading increases in storm water runoff: TSS - 48,410 lbs/year; total phosphorus - 176 lbs/year; and oil and grease - 821 lbs/year. The Service anticipates that pollutant loads in the surface water will increase over the long term as the watershed develops. Through the remaining term of the CGP, EPA predicted post-construction storm water pollutant loadings to the watershed would increase 0.04% for total phosphorus and 0.05% above the total existing loads. Similar increases in other pollutants can be expected to occur because the above parameters were selected to represent the major categories of pollutants. These impacts will continue for 50 to 100 years because these developments will be relatively permanent. (Table 13 EPA's Analysis)

Since water quality at Barton Springs is impacted by the quality and quantity of storm water runoff, the level of contamination at the springs may increase as urbanization continues to expand over the watershed (City of Austin 1997). Some increased levels of sedimentation pesticides, and/or heavy metals, may be deposited salamander habitat during storm events. Water quality data has indicates that multiple contaminants are present at some level, but it is not know if this is frequently or periodically, in salamander habitat. Although the temporal and spacial distribution of this data does not allow one to make a firm conclusion about possible effects to the salamander, the Service is concerned about the possible additive and synergistic effects of various contaminants to the salamander's prey base.

Polyaromatic Hydrocarbons

Increases in PAH concentrations in watershed sediments are projected in the LCRA study for a 25-year period (LCRA 2001). These projections are based on a correlation between increases in vehicle miles driven and increases in PAHs that allowed an estimation of both current and future concentrations within the watershed. The LCRA study predicted an annual increase in daily vehicle miles traveled of 117,355 or a PAH concentration of 185 mg/kg. This translates into a 4% annual increase relative to current conditions or about a 5% increase for the remaining term of the permit. Again, some fraction of the loading may be expressed at Barton Springs.

Sediment criteria suggested by EPA (1997), MacDonald et al. (2000), and TNRCC (2000) most probably will continue to be exceeded, leading the Service to conclude that adverse effects to the salamander may occur. The number of times and the degree to which these effects levels (Threshold Effects Concentrations, Threshold Effects Levels, Possible Effects Levels) were exceeded in salamander habitat suggest that direct effects to the aquatic community may be occurring and there exists the potential for synergistic effects among PAHs and other pollutants.

Generally, the toxic effects of chemicals are greater on younger life stages of aquatic organisms. Salamander eggs and juveniles live on and near the bottom substrate. These younger life stages could be impacted at the reported levels of contaminants. We have no data to confirm this suspicion because tests have not been performed on these younger animals.

Most of the PAHs come from roadways and the Service is committed to looking carefully at the execution of existing biological opinion conditions covering these activities as well as future consultations with the Federal Highway Administration or where Texas Department of Transportation is a party.

Pesticides

Pesticide levels, including insecticides, herbicides, and fungicides may increase in salamander habitat. Pesticide use associated with residential, commercial, civic, and industrial land use may, unless adequately controlled, result in changes to levels found in surface water as the watershed develops. These contaminants could impact the salamander population in a variety of ways based on the exposure. Exposure may include contact with or ingestion of contaminated water, sediments, or food items (Hill 1995). Because of their semipermeable skin, the development of their eggs and larvae in water, and their position in the food web, salamanders can be exposed to pollutants in their breeding and foraging habitats. Furthermore, pesticides probably change the quality and quantity of salamander prey and habitat (Bishop and Pettit 1992). Toxic effects to amphibians from pesticides may be either lethal or sublethal (Rand et al. 1995) and Hayes (et al. 2002) found morphological and developmental aberrations and changes in biochemical processes in frogs exposed to low levels of atrazine.

Atrazine, diazinon, carbaryl, and many organochlorine pesticides have been detected in either water or sediment in salamander habitat. Construction activities can mobilize these chemicals. An increase in the surface water loading could increase the frequency, duration, or concentration of these pesticides. Some fraction of that loading may reach Barton Springs and may increase the potential for lethal and sublethal impacts to salamander's prey base.

Heavy Metals

Metals in stormwater have been associated with many common activities in an urban setting, such as vehicle use, paints, metal corrosion, wood preservatives, paving materials, deicing salts, etc. Metals have been detected in sediments as well as the water column in Barton Springs. Increases in metals associated with post construction land use in surface water runoff may occur unless adequately controlled. Heavy metals can impact an organisms survival, growth, reproduction, development, behavior, learning, and metabolism (Eisler 1988a, Pain 1995). Adverse effects increase with younger life stages and long exposures (Eisler 1988a, Pain 1995). Synergistic and additive effects may also occur when heavy metals are mixed with other toxic chemicals (Eisler 1988a). However, at the levels found, and given the temporal and spacial distribution, it is likely that the effects will be minimal.

Several heavy metals have been detected in Barton Springs. And it is possible that this may result in an increase in levels of heavy metals at spring sites. Heavy metals can impact an organisms survival, growth, reproduction, development, behavior, learning, and metabolism (Eisler 1988a, Pain 1995). Adverse effects increase with younger life stages and long exposures (Eisler 1988a, Pain 1995). Synergistic and additive effects may also occur when heavy metals are mixed with other toxic chemicals (Eisler 1988a). However, at the levels found, and given the temporal and spacial distribution, it is likely that the effects will be minimal.

Summary

Loadings of pollutants in surface water do not equate to loadings discharged from the Springs. At least two major factors influence the connection between surface water loads and spring water discharge loads. First, not all surface water is recharged into the aquifer. Second, studies suggest that pollutant loadings for at least some parameters entering from recharge are attenuated to some degree by the aquifer.

However, several contaminants in salamander habitat sediments have been found at concentrations that may have the potential to affect invertebrates eaten by the salamander. The duration of these toxic events from water borne pollutants are not temporally or spatially constant. Some of these contaminants (atrazine, diazinon, PAHs, arsenic, cadmium, copper, mercury, nickel, silver, and others) at some time exceeded criteria for probable effects to benthic animals. Multiple pollutants are present in salamander habitat at some time and synergistic and additive effects are of concern. Sediment deposition can be a long-term impact. If pollutants continue to increase in the Spring, the maintenance and protection of salamander habitat quality and subsequently the breeding, feeding, and sheltering behaviors of the salamander could be affected. The Service believes that enhanced compliance monitoring and habitat monitoring will minimize or avoid any of the potential adverse effects attributed to the action under this consultation.

V. Cumulative Effects

Cumulative effects include effects of future State, tribal, local, or private actions that are reasonably certain to occur in the action area considered in this biological opinion. Future federal actions that are unrelated to the proposed action are not considered in this section since they require separate consultation pursuant to section 7 of the ESA.

State, local, and private construction actions disturbing less than five acres do not require CGP coverage. Single family home construction and small commercial construction would be the most common types of construction that disturb less than five acres. The Service estimates that the total number of acres developed under this category will be less than 200. With the current subdivision rules in Travis and Hays Counties, most single family construction will occur on relatively large lots and may not contribute significantly to water quality degradation. Increases in vehicle miles traveled in the watershed, wastewater treatment impacts, and home chemical use will result form this type of development. Overall, construction on less than five acres will add a small amount of pollutants to the water quality within the Barton Springs watershed and hence in salamander habitat. The impact to the salamander would be relatively small but would be additive with the other impacts.

The Service contacted Hays County, the Village of Dripping Springs, the Village of Bee Caves, Travis County, and the City of Austin to estimate the amount of development in the watershed. Hays County estimated that several hundred acres are under construction in areas that do not fall within any municipal jurisdiction (A. Walther, Director of Environmental Health, Hays County, pers. comm.). The Village of Dripping Springs, in Hays County, estimated about 1,000 acres of construction within their City limits and Extraterritorial jurisdiction (Ginger F., City Dripping Springs, pers. comm.). The Village of Bee Caves estimated about 2,000 acres of construction within their City limits and Extraterritorial jurisdiction (E. Beard, Building Inspector, Village of Bee Caves, pers. comm.). Travis County used a similar process to determine that about 450 acres were developed in 2001 in areas that do not fall within any municipal jurisdiction (K. Connally, Environmental Specialist, Travis County, pers. comm.). The City of Austin, using their development database and current inspection records determined that about 2,000 acres are under construction in the Barton Springs watershed within their Corporate limits and Extraterritorial jurisdiction (P. Murphy, Environmental Officer, City of Austin, pers. comm.). Summing these estimates results in about 6,600 acres under some stage of development in the watershed. About 1,600 of these acres are expected to be under construction during the CGP's remaining permit term. The other 4,400 acres of these projects will be constructed in the future and will need to be covered under the TNRCC's construction general permit. EPA and the Service have consulted on TNRCC's assumption of the CGP program and the effects on the Barton Springs salamander. TNRCC's CGP program is not within the action of this consultation.

VI. Conclusion

After reviewing the current status of the salamander, the environmental baseline for the action area, the effects of the proposed action, and the cumulative effects, it is the Service's biological opinion that the continued operation of the CGP in the Barton Springs watershed, as proposed, is not likely to jeopardize the continued existence of the Barton Springs salamander. As discussed above, the construction stormwater general permit contains measures to minimize stormwater discharges during construction. In addition, the State of Texas and local governments have implemented land use controls that address the quality and quantity of storm resulting from post-construction development. There is uncertainty regarding the extent to which the fraction of total loadings attributed to this action translate into increased pollutant levels in the salamander's habitat. Moreover, the best available information indicates that the incremental contribution of pollutants from projects covered by the permit during the next fourteen months is expected to be small, provided the permit and applicable local ordinances are followed. To ensure compliance with its permit, EPA has committed to enhanced oversight, monitoring, and enforcement, in coordination with FWS, Texas and local authorities. The protections contained in the existing EPA, State and local requirements, coupled with enhanced compliance assurance efforts, will ensure that the CGP is not likely jeopardize the continued existence of the salamander. No critical habitat has been designated for this species, therefore, none will be affected.

INCIDENTAL TAKE STATEMENT

Section 9 of the Act and Federal regulation pursuant to section 4(d) of the Act prohibit the take of endangered and threatened species, respectively, without special exemption. Take is defined as to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture or collect, or to attempt to engage in any such conduct. Harm is further defined by FWS to include significant habitat modification or degradation that results in death or injury to listed species by significantly impairing essential behavioral patterns, including breeding, feeding, or sheltering. Harass is defined by FWS as intentional or negligent actions that create the likelihood of injury to listed species to such an extent as to significantly disrupt normal behavior patterns which include, but are not limited to, breeding, feeding or sheltering. Incidental take is defined as take that is incidental to, and not the purpose of, the carrying out of an otherwise lawful activity. Under the terms of section 7(b)(4) and section 7(o)(2), taking that is incidental to and not intended as part of the agency action is not considered to be prohibited taking under the Act provided that such taking is in compliance with the terms and conditions of this Incidental Take Statement.

The measures described below are non-discretionary, and must be undertaken by the (agency) so that they become binding conditions of any grant or permit issued to the (applicant), as appropriate, for the exemption in section 7(o)(2) to apply. The (agency) has a continuing duty to regulate the activity covered by this incidental take statement. If the (agency) (1) fails to assume and implement the terms and conditions or (2) fails to require the (applicant) to adhere to the terms and conditions of the incidental take statement through enforceable terms that are added to the permit or grant document, the protective coverage of section 7(o)(2) may lapse. In order to monitor the impact of incidental take, the (agency or applicant) must report the progress of the action and its impact on the species to the Service as specified in the incidental take statement. [50 CFR §402.14(i)(3)]

Amount or Extent of Take

The Service anticipates that the CGP could result in a some incremental increase in the levels of certain pollutants in salamander habitat. Such pollutants, when present at elevated levels, have the potential to significantly impair the salamander's essential behavior patterns. In the accompanying biological opinion, the Service determined that the extent of any take attributable with the CGP is not likely to jeopardize the continued existence of the salamander. The Service anticipates that incidental take of salamanders will be difficult to detect because of uncertainty regarding the extent to which discharges to surface waters under the CGP translate into water quality alterations in the habitat of the salamander authorized by CGP.

Reasonable and Prudent Measures

The Service believes the following reasonable and prudent measure is necessary and appropriate to minimize any take associated with the CGP:

EPA shall minimize the effects of the CGP on the habitat of the Barton Springs salamander by ensuring compliance with the CGP.

Terms and Conditions

In order to be exempt from the prohibitions of section 9 of the Act, EPA must comply with the following terms and conditions, which implement the reasonable and prudent measures described above and outline required reporting/monitoring requirements. These terms and conditions are non-discretionary.

1. EPA will access the Notice of Intent database to identify Notices being submitted for projects in the Zone.

2. Based on review of Notice of Intent information, EPA will notify operators of projects within the Zone of their:

   a. duty to comply with the terms and conditions of the Construction General Permit (CGP), and

   b. obligation to comply with applicable State and local water quality requirements.

3. EPA Region 6 will convene monthly telephone conferences with the Fish and Wildlife Service Austin Ecological Services and with the Texas Natural Resource Conservation Commission (TNRCC), to discuss monitoring and enforcement compliance with the CGP . The three parties will gather information, and will discuss review specific sites recommended by third parties related to the compliance with the CGP in the Barton Springs area. The City of Austin will also be invited to participate in the calls. The Region will conduct random and targeted inspections of construction sites (to include presently incomplete but permitted construction) in the Barton Springs area in addition to conducting outreach activities for developers and builders in the area. The Region will also be following up with appropriate action on violations identified

at the construction sites in the area. EPA will maintain the official reports and record of any EPA inspections monitoring and compliance actions. EPA and the Service will reassess the need for monthly calls on an annual basis.

4. EPA will provide technical experts to discuss those water quality measures of greatest significance to the health of the Barton Spring Salamander. EPA will propose a meeting with the Service, TNRCC, and the City of Austin, within 30 days of the date of the final biological opinion to jointly determine the subjects and frequency of the monitoring and reporting requirements.

The Service believes that adherence with the RPMS and terms and conditions should minimize any incidental take associated with the CGP. If, however, monitoring agreed to under term and condition 4 detects any significant impact to water quality in the salamander habitat due to the CGP, EPA shall reinitiate consultation.

CONSERVATION RECOMMENDATIONS

Conservation recommendations are discretionary agency activities to minimize or avoid adverse effects of a proposed action on listed species or critical habitat, to help implement recovery plans, or to develop information. The Service, therefore, recommends that EPA should, within the limits of the Agency's authority and resources, implement the following items:

1. In accordance with the Memorandum of Agreement signed between EPA and the Services on February 22, 2001, EPA should work with FWS to jointly request priority for research funding for: (a) a comprehensive study to understand and control nonpoint source pollution in the Barton Springs Watershed, and (b) a comprehensive monitoring program on the aquifer to identify concentrations and loading of storm water pollutants from all of the streams which feed the Barton Springs segment of the Edwards Aquifer.

2. Provide funding to support studies on the effects of contaminants on the Barton Springs salamander.

3. Support and encourage the State of Texas to utilize available Federal Grant funding, including 106 funds, to support monitoring programs designed to facilitate recovery of the endangered salamander.

4. Utilize its authority under the programs it administers, to protect water and sediment quality to the maximum extent possible. This should be done thorough completion of the ongoing 7(a)(1) consultation process.

5. EPA should develop national sediment criteria and then work with the State of Texas and the Service to develop enforceable sediment criteria in the Texas Water Quality Standards as necessary to protect the salamander, its food, and habitat. The parameters addressed

should be based on all available information including that presented in the EPA water quality assessment on this opinion.

6. EPA should develop national water quality criteria for pesticides registered by EPA which could effect the Barton Springs watershed. If monitoring documents that established pesticide criteria levels are exceeded, EPA should take appropriate actions to address this situation as soon as practicable.

7. For any parameter in the watershed found to be exceeding any established criteria, EPA should, through the 303(d) process, require the establishment of Total Maximum Daily Loads including specific load allocations for all contributing sources for the parameter as soon as possible.

8. In carrying out its oversight responsibilities, EPA should perform a thorough review to assure that the conditions under the State construction stormwater permit are at least as protective as the protections in the current EPA permit.

In order for the Service to be kept informed of actions minimizing or avoiding adverse effects or benefitting listed species or their habitats, the Service requests notification of the implementation of any conservation recommendations.

REINITIATION NOTICE

This concludes formal consultation on EPA's continued use of the CGP in the Barton Springs watershed. As provided in 50 CFR §402.16, reinitiation of formal consultation is required where discretionary Federal agency involvement or control over the action has been retained (or is authorized by law) and if: (1) the amount or extent of incidental take is exceeded; (2) new information reveals effects of the agency action that may affect listed species or critical habitat in a manner or to an extent not considered in this opinion; (3) the agency action is subsequently modified in a manner that causes an effect to the listed species or critical habitat not considered in this opinion; or (4) a new species is listed or critical habitat designated that may be affected by the action.

Please contact me at 512-490-0057 if you have any questions or would like to discuss any part of this biological opinion.

Sincerely,

H Dale Hall

H. Dale Hall
Acting Regional Director

Attachments

cc: (w/ attachments)
Regional Solicitor, Albuquerque, NM
Chief, Division of Endangered Species, Region 2
Section 7 Coordinator, Region 2
Environmental Contaminants Coordinator, Region 2

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Figure 1
Barton Springs Edwards Aquifer and Contributing Zone

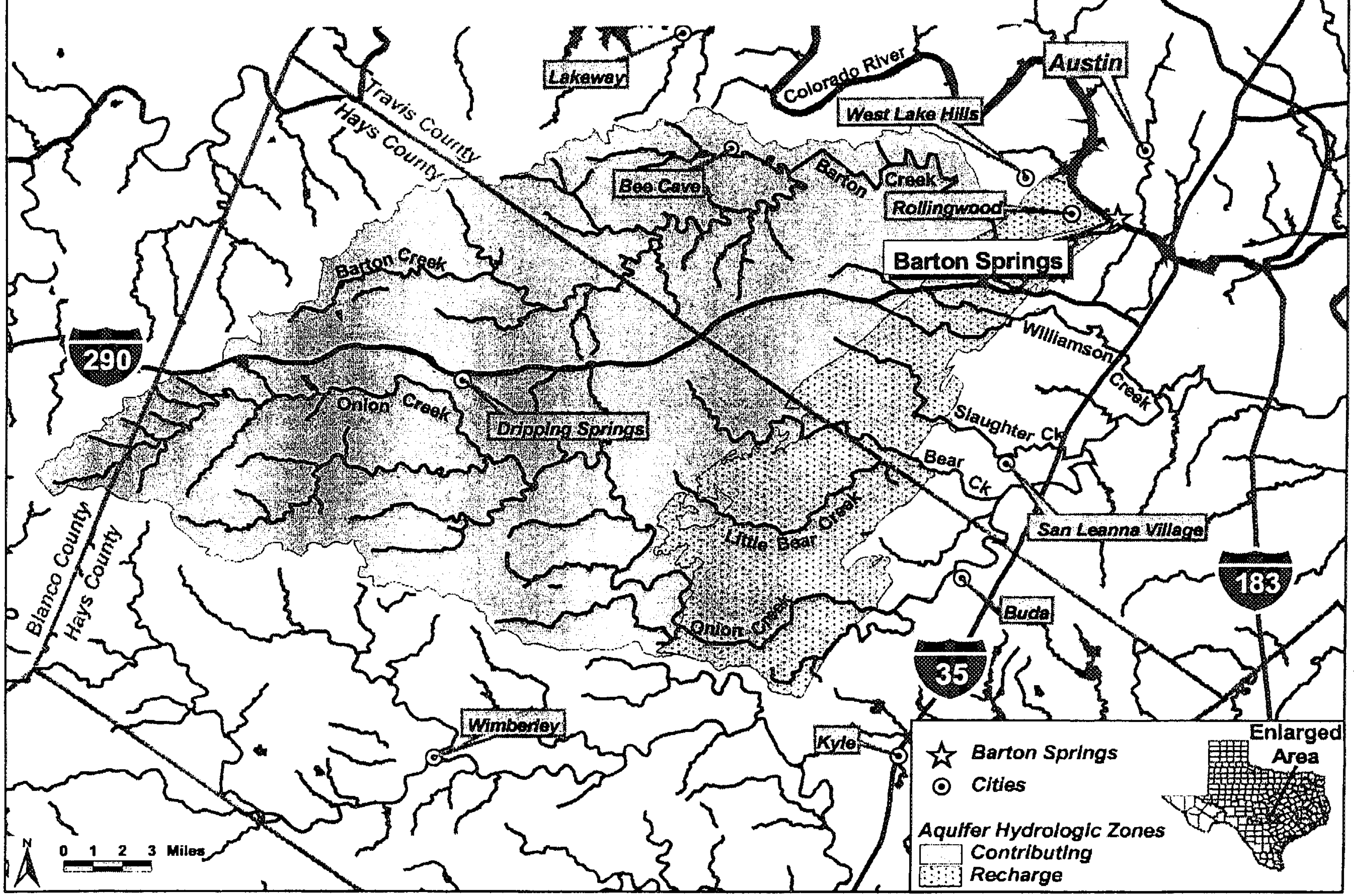

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Figure 2. City of Austin - Analysis of Changes in Creek Water Quality with Construction Activity and Increased Development.

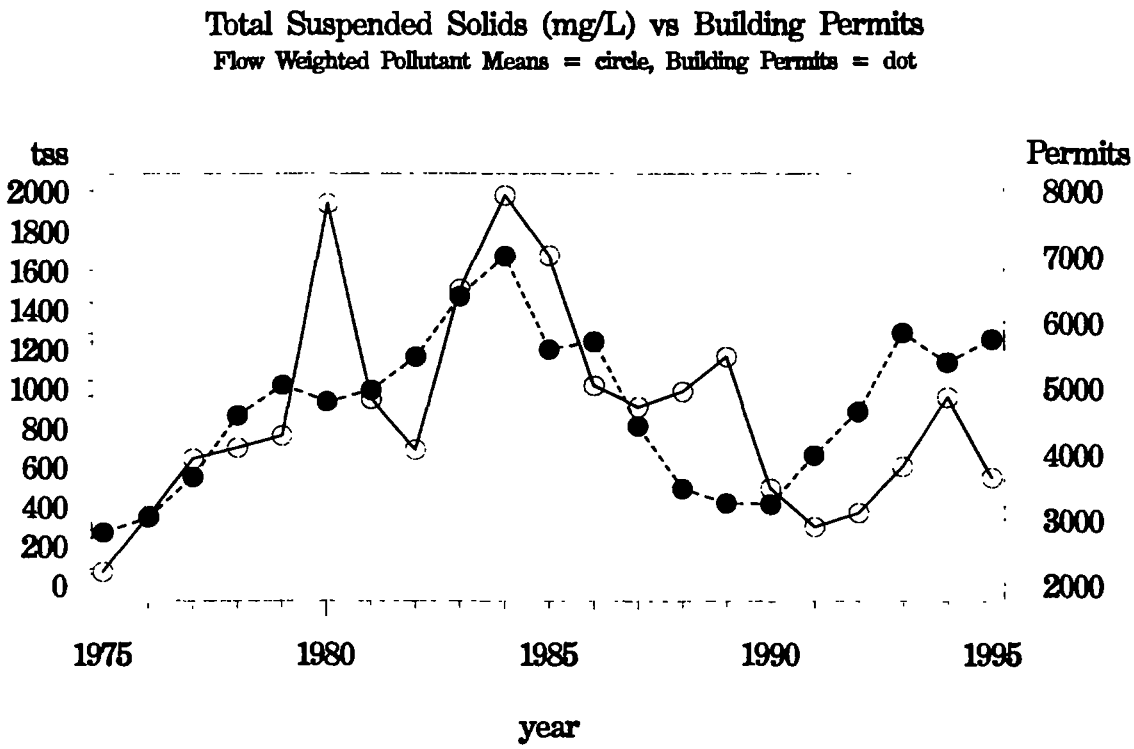

Table 1.

BARTON SPRINGS BENTHIC MACROINVERTEBRATES

List compiled by the City of Austin

(Continued from bottom of columns one and two)

Organism	Location	Organism	Location
NON-INSECTA		PLECOPTERA	
TURBELLARIA		Leuctridae	
Dugesia tigrina (Girard)	[BC, BSP, ES, SGS, UPS]	Zealeuctra hitei Ricker & Ross	[BC, BSP, ES, SGS, UPS]
OLIGOCHAETA	[BC, BSP, ES, SGS, UPS]	TRICHOPTERA	
Dero sp.		Helicopsychidae	
Limodrilus sp.		Helicopsyche borealis (Hagen)	[BC, BSP, SGS, UPS]
Pristina sp.		Hydroptilidae	
additional genera		Hydroptila spp.	[BC, BSP, ES, SGS, UPS]
NEMATODA	[BC, BSP, ES, SGS, UPS]	Ithytrichia clavata Morton	[BC, BSP]
COELENTERATA		***	[SGS]
Hydra sp.	[BC, BSP, ES, SGS, UPS]	Metrichia nigritta Ross	[BC, BSP, UPS]
HIRUDINIA		Neotrichia nr. canixa Mosely	[BC]
Helobdella elongata Castle	[BC, BSP]	Oxyethira sp.	[BC, BSP]
Helobdella stagnalis Linneaus	[BC, BSP]	Hydropsychidae	
GASTROPODA		Cheumatopsyche pettiti (Banks)	[BC, BSP]
Ancylidae		Leptoceridae	
Ferrissia fragilis Tyron	[BC, BSP]	Nectopsyche gracilis (Banks)	[BC, BSP, SGS]
Hydrobiidae		Oecetis avara (Banks)	[BC, BSP]
Cincinnatia cincinnatiensis (Anthony)	[BC, BSP]	Oecetis cinerascens (Hagen)	[BC, BSP]
Phreatodrobia nugax nugax (Pilsbry & Ferriss)		Oecetis inconspicua (Walker)	[BC, BSP]
Phreatodrobia punctata Hersler & Longley	[ES]	Triaenodes injusta (Hagen)	[BSP]
Stygopyrgus bartonensis Hersler & Longley*	[ES]	Philopotamidae	
Lymnaeidae		Chimarra aterrima Hagen	[BC, BSP]
Fossaria modicella Say	[BC, BSP, UPS]	Chimarra obscura (Walker)	[BC, BSP, SGS]
Physidae		Polycentropodidae	
Physella virgata rhyssa (Pilsbry)	[BC, BSP]	Polycentropus sp	[BC, SGS, UPS]
Planorbidae		Cernotina calcea Ross	[BSP]
Gyraulus parvus Say	[BC, BSP]		
Helisoma anceps anceps (Menke)	[BC, BSP]	LEPIDOPTERA	
Planorbella tenue (Dunker)	[BC, BSP]	Pyralidae	
Pleuroceridae		Petrophila sp.	[BSP, SGS, UPS]
Elimia comalensis Pilsbry	[BC, BSP]		
Thiaridae		COLEOPTERA	
Melanoides tuberculata (Müüller) **	[SGS]	Dryopidae	
		Helichus lithophilus Germer	[BC, BSP]
PELECYPODA/BIVALVIA			
Corbiculidae		Dytiscidae	
Corbicula fluminea Müüller	[BC, BSP]	Copelatus chevrolati renovatus Guignot	[BC, ES]
		Heterosternuta diversicornis (Sharp)	[BC, BSP]
HYDRACHNIDIA		Laccophilus vacaensis chihuahuae Zimmerman	[BC, ES]
Arrenurus sp.	[BC, BSP]	Liodessus obscurellus (LeConte)	[ES, SGS]
Hydrachna sp.	[BC, BSP]	Neoclypeodytes spp.	[BSP, ES]
Lebertia sp.	[BC, BSP]	Neoporus dimidiatus (Gemminger & von Harold)	[BC, BSP]

Oxus sp.	[BC, BSP]
additional genera	[BC, BSP]
AMPHIPODA	
Artesiidae	
Artesia subterranea Holsinger	[BSP]
Hyalellidae	
Hyalella azteca (Saussure)	[BC, BSP, ES, SGS, UPS]
ISOPODA	
Asellidae	
Caecidotea nr. pilus (Steeves)	[SGS]
DECAPODA	
Cambaridae	
Procambrus clarki (Girard)	[BC, BSP, ES, SGS, UPS]
Palaemonidae	
Palaemonetes kadiakensis Rathbun	[BC, BSP]
BRANCHIPODA	
Cladocera	[BC, BSP, ES, SGS, UPS]
COPEPODA	[BC, BSP, ES, SGS, UPS]
OSTRACODA	
Cyprididae	
Chlamydotheca sp	[BC, BSP, SGS]
Cypricercus sp	[BC, BSP, SGS]
Cypridopsidae	
Potamocypris sp.	[BC, BSP, ES?, SGS]
INSECTA	
COLLEMBOLA	
Sminthuridae	[BC, BSP, SGS]
EPHEMEROPTERA	
Baetidae	
Apobaetis indeprensus Day	[BC, BSP]
Callibaetis californicus Banks	[BC, BSP]
Callibaetis floridanus Banks	[BC, BSP, ES, SGS]
Callibaetis pictus (Eaton)	[BC, BSP, SGS]
Procloeon viridoculare (Berner)	[BC, BSP]
Caenidae	
Brachycercus flavus Traver	[BC, BSP]
Caenis latipennis Banks	[BC, BSP]
Caenis hilaris (Say)	[BC, BSP]
Emphemeridae	
Hexagenia bilineata (Say)	[BC, BSP]
Hexagenia limbata Serville	[BC, BSP]
Heptageniidae	
Stenonema femoratum (Say)	[BC, BSP, ES, SGS, UPS]
Leptohyphidae	
Tricorythodes albilineatus Berner	[BC, BSP]
Tricorythodes explicatus (Eaton)	[BC]
ODONATA	
Aeshnidae	

Elmidae	
Hexacylloepus ferrugineus (Horn)	[BC, BSP]
Microcylloepus pusillus (LeConte)	[BC, BSP, SGS]
Neoelmis caesa (LeConte)	[BC, BSP, SGS]
Gyrinidae	
Gyrinus sp.	[BC, BSP, ES]
Halipidae	
Haliplus deceptus Matheson	[BC, BSP, SGS]
Wehenke	[BC, BSP, ES, SGS]
Peltodytes sexmaculatus Roberts	[BC, BSP]
Hydrophilidae	
Berosus sp.	[BC, BSP]
Cymbiodyta chamberlaini Smetana	[BC, BSP]
Hydrophilus triangularis Say	[ES]
Tropisternus blatchleyi blatchleyi d''Orchymont	[BC, ES]
Tropisternus lateralis nimbatus (Say)	[ES]
Psephenidae	
Psephenus texanus Brown & Arrington	[BC, BSP, ES, SGS, UPS]
DIPTERA	
Ceratopogonidae	
Bezzia sp.	[BC, BSP]
Dasyhelea sp.	[BC, BSP]
Palpomyia tibialis (Meigen)	[BC, BSP]
Probezzia sp.	[BC, BSP]
Chironomidae	
Ablabesmyia sp.	[BC, BSP, ES, SGS]
Chironomus sp.	[BC, BSP, ES, SGS]
Cladotanytarsus sp.	[BC, BSP, ES, SGS]
Cryptochironomus sp.	[BC, BSP, ES, SGS]
Cryptotendipes sp.	[BC, BSP, ES, SGS]
Fittkauimyia sp	[BC, BSP, ES, SGS]
Polypedilum sp.	[BC, BSP, ES, SGS]
Tanytarsus sp.	[BC, BSP, ES, SGS]
Zavreliella sp.	[BC, BSP, ES, SGS]
additional genera	
Simulidae	
Simulium spp	[BC, BSP]
HEMIPTERA	
Belastomatidae	
Belostoma bakeri Montandon	[BC, BSP]
Corixidae	
Trichocorixa sp.	[BC, BSP, ES, SGS]
Gerridae	
Aquarius sp.	[BC, BSP, ES]
Naucoridae	
Cryphocricus hungerfordi Usinger	
Pelocoris biimpressus biimpressus Montandon	[BSP]
Mesoveliidae	
Mesovelia mulsanti White	[BC, BSP, ES]

Anax junius (Drury)	[BC, BSP]	Veliidae	
Corduliidae		*Rhagovelia* sp.	[BC, BSP, SGS]
Epitheca costalis (Séélys)	[BC, BSP, SGS]	*Microvelia paludicola* Champion	[BC, BSP, ES]
Gomphidae			
Dromogomphus spinosus Séélys	[BC, BSP]	MEGALOPTERA	
Erpetogomphus designatus Hagen in Séélys	[BC, BSP]	Sialidae	
Coenagrionidae		*Sialis velata* Ross	[BC, BSP]
Argia immunda (Hagen)	[BC, BSP, SGS]		
Argia moesta (Hagen)	[BC, BSP]		
Argia translata Hagen in Séélys	[BC, BSP, SGS]		
Enallagma signatum (Hagen)	[BC, BSP]		
Enallagma geminata Kellicott	[BC, BSP]		
Libellulidae			
Erythemis simplicicollis (Say)	[BC, BSP, SGS?]		
Libellula luctousa Burmeister	[BC, BSP?]		
Libellula incesta Hagen	[BSP]		
Pachydiplax longipennis (Burmeister)	[BC, BSP]		
Orthemis ferruginea (Fabricius)	[BC, BSP]		

BC	Barton Creek (below Barton Springs Pool)
BSP	Barton Springs Pool
ES	Eliza Springs
SGS	Sunken Garden Springs (Old Mill Springs)
UPS	Upper Barton Springs
*	Endemic (monotypic genus, currently only known from phreatic waters associated with Eliza Springs, additionally no live specimens yet known, only shells collected)
**	Introduced Asian or African species. (point of origin, either Africa or SE Asia)
***	Not collected as part of this study (reported in "Texas Caddisflies", S. W. Edwards. 1973. T. Journal of Science 24: 491-51.

Table 2. Summary of Incorporated Municipalities and Their Associated Extraterritorial Jurisdictions (ETJ) for the Barton Springs Watershed (LCRA 2001).

Municipality and Jurisdiction	Acres	Percent of Watershed
City of Austin (incorporated)	22,383.7	9.3%
City of Austin (limited purpose ETJ)	5,469.9	2.3%
City of Austin (2-mile ETJ)	23,587.0	9.8%
City of Austin (5-mile ETJ)	17,835.8	7.4%
City of Buda (incorporated)	90.6	0.0%
City of Dripping Springs (incorporated)	1,908.9	0.8%
City of Dripping Springs (ETJ)	69,334.6	28.9%
City of Hays (incorporated)	2,539.4	1.1%
City of Rollingwood (incorporated)	440.8	0.2%
City of Sunset Valley (0.5-mile ETJ)	154.4	0.1%
City of Sunset Valley (incorporated)	724.4	0.3%
City of West Lake Hills (incorporated)	763.4	0.3%
Mountain City (incorporated)	157.4	0.1%
Mountain City (0.5-mile ETJ)	840.3	0.4%
Village of Bear Creek (incorporated)	739.4	0.3%
Village of Bee Cave (incorporated)	1,200.4	0.5%
Village of Bee Cave (1-mile ETJ)	5,581.8	2.3%
Village of Lakeway (incorporated)	118.8	0.1%
TOTAL	153,871.0	64.2%

Table 3. Edwards Aquifer Regulations History.

Regulation	Effective Date	Agency
Board Order No. 72-0217-9	February 17, 1972	Texas Water Quality Board
Board Order No. 72-1128-4	November 28, 1972	Texas Water Quality Board
Board Order No. 74-0326-4	March 27, 1974	Texas Water Quality Board
Board Order No. 75-0128-20	January 28, 1975	Texas Water Quality Board
Board Order No. 77-0303-3	March 3, 1977	Texas Water Quality Board
Chapter 156.20	February 2, 1978	Texas Water Development Board
31 TAC Chapter 331 Subchapter A	August, 1984	Texas Dept of Water Resources
31 TAC Chapter 331 Subchapter B	May 21, 1985	Texas Dept of Water Resources
31 TAC Chapter 313	July 2, 1986	Texas Water Commission
31 TAC Chapter 313	February 23, 1988	Texas Water Commission
31 TAC Chapter 313	March 21, 1990	Texas Water Commission
31 TAC Chapter 313	January 21, 1992	Texas Water Commission
30 TAC Chapter 313	September 1, 1993	Texas Natural Resource Conservation Commission
30 TAC Chapter 213	December 27, 1996	Texas Natural Resource Conservation Commission
30 TAC Chapter 213	November 14, 1997	Texas Natural Resource Conservation Commission
30 TAC Chapter 213	June 1, 1999	Texas Natural Resource Conservation Commission

On December 27, 1996 30 TAC Chapter 313 was vacated and 30 TAC Chapter 213 became effective. The Rules went into effect June 1, 1999.

Table 4. EPA Resources for Surface and Ground Water Quality Determinations.

Northern Hays and Southwestern Travis Counties Water Supply System Environmental Impact Study, Oct 2001	Transmittal, Texas Capitol Area Builders Association, Endangered Species '7 Consultation - NPDES CGP in Barton Springs Zone, April 1, 2002	Briefing handout, Barton Springs Zone Development Report, Staff Presentation to COA Mayor and City Council, December 2, 1999.
Memorandum of Understanding, The Service and LCRA, May 2000.	Transmittal, SWCA Environmental Consultants, Comments on 27-28 March 2002 Barton Springs Salamander Technical Workshop, April 2, 2002	Briefing handout, Hydrogeology of the Barton Springs Segment of the Edwards Aquifer, Nico Hauwert, City of Austin, March 27, 2002
The Service's Biological Opinion, Consultation No. 2-15-00-F-1135, Effects of the Proposed Northern Hays County and Southwester Travis Count Water Supply System (December 2001)	Transmittal, City of Austin Comments on The Service's Biological Opinion Technical Review, April 3, 2002	Briefing handout, Spring Water Quality in the BSZ and Similarities and Differences In Barton and Upper Barton Springs, David Johns, City of Austin, March 27, 2002
City of Austin Habitat Conservation Plan for The Service Section 10(a)(1)(B) permit to City of Austin for Operation and Maintenance of Barton Springs Pool and the adjacent springs.	Transmittal, Save Our Springs Alliance, April 3, 2002	Briefing handout, Water Quality Trends at Barton Springs, Martha Turner, City of Austin, March 27, 2002
30 TAC 213, Edwards Aquifer Rules (June 1999)	The Barton Creek Report, City of Austin, Water Quality Report Series COA-ERM/ 1997, April 22, 1997	Briefing handout, Construction Impacts, Ed Peacock, City of Austin, March 27, 2002
Groundwater Tracing Study of the Barton Springs Segment of the Edwards Aquifer, August 2001 (DRAFT)	Update of Barton Springs Water Quality Data Analysis - Austin, Texas, Water Quality Report Series COA-ERM 2002-2, May 16, 2000	Briefing handout, Sediment Quality in Austin Watersheds with Focus on Barton Springs Zones, Leila Gosselink, City of Austin, March 27,2002
City of Austin Municipal Separate Storm Sewer System (MS4) Permit, Fact sheet and Enforcement file.	Water Quality Assessment of South-Central Texas, Descriptions and Comparisons of Nutrients, Pesticides, and Volatile Organic Compounds at Three Intensive Fixed Sites, USGS Water Resources Investigations Report 99-4155	Briefing handout, Stormwater Pollution and Its Control in the Barton Springs Zone, Pat Hartigan, City of Austin, March 27, 2002

The Service's Biological Opinion on City of Austin Municipal Separate Storm Sewer System (MS4) Permit	Texas Department of Transportation Municipal Separate Storm Sewer System (MS4) Permit, Fact sheet and Enforcement file.	Briefing handout, Soluable Contaminants, Barbara Mahler, USGS, March 27, 2002
Clark, A.K.. 2000. Vulnerability of ground water to contamination, Edwards aquifer recharge zone, Bexar County, Texas, 1998. U.S. Geological Survey, Water-Resources Investigations Report 00-4149	The Service's Biological Opinion on Texas Department of Transportation Municipal Separate Storm Sewer System (MS4) Permit.	Briefing handout, Suspended and Bottom Sediment Quality, Peter Van Metre, USGS, March 27, 2002
Hauwert, N.H., J.W. Sansom, D.A. Johns, T.J. Aley. 2002. Groundwater tracing study of the Barton Springs segment of the Edwards aquifer, Draft Report. Barton Springs/Edwards Aquifer Conservation District and the City of Austin.	Scanlon, B.R., R.E. Mace, A.R. Dutton, and R. Reedy. 2000 Predictions of groundwater levels and spring flow in response to future pumpage and potential future droughts in the Barton Springs segment of the Edwards aquifer. Bureau of Economic Geology, The University of Texas at Austin, contract report. Prepared for Lower Colorado River Authority	Slade, R.M., Jr., Dorsey, M.E., and Stewart, S.L. (1986). Hydrology and water quality of the Edwards aquifer associated with Barton Springs in the Austin Area, Texas. U.S. Geological Survey. Water-Resources Investigations Report 86-4036.

Table 5. The Magnitude and Percent Change in Selected Water Quality Constituents over a 20 to 25 Year Time Period at Barton Springs in Zilker Park in Austin, Texas. (Adapted from the City of Austin, Environmental Resources Management, Watershed Protection Department's Water Quality Report Series (COA-ERM 2000-2) (May18, 2000).

Parameter	**Flow Condition**	**Normalized Period Medians**			
		1975-1979 or 1980-1984^ Median	1995-1999 Median	Change over approx. 20 years	Percent Change ($p \leq 0.05$)
Dissolved Oxygen (mg/l)	Baseflow without Recharge	6.8	5.7	-1.1	-16%
Organic Carbon (mg/l)	Storm flow	1.5	3.4	1.9	127%
Specific Conductance (iS/cm)	Baseflow without Recharge	655	677	22	3%
	Baseflow with Recharge	590^	646	56	9%
	Storm flow	624	642	18	3%
Sulfate (mg/l)	Baseflow without Recharge	28.3^	38 8	10.5	37%
Turbidity (NTU)	Storm flow	5.3	7	1.7*	32%*

^ Actually 1980, 1983 & 1984, since 1981 & 1982 were removed from the analysis due to a sewer line break

* Significant at the 0.1 level, but not at the 0.05 level

Table 6. Contribution to Aquifer from Creeks Crossing Recharge Zone.

Creeks Crossing the Recharge Zone	**% of Total Recharge Contributed**	**Rate of Recharge (cfs)**
Barton	28	30-70
Williamson	6	13
Slaughter	12	52
Bear	10	33
Little Bear	10	~30
Onion	34	~120

1- Maximum recharge rates may be greater during flood flow. Total max recharge rate may reach 350-400 cfs(Slade 1986).

Table 7. Metals and poly-aromatic hydrocarbon (PAH) sediment data from Barton Springs Pool. These data were from grab samples taken from the bottom of the stream. These data are from the City of Austin sediment quality database.

					Barton Springs Pool										
Metals (mg/kg)	TNRCC[1]	Consensus[2] TECs	EPA TELs[3]	EPA PELs[3]	04/20/95	04/20/95	07/25/95	03/22/99	03/22/99	05/05/99	11/19/99	05/03/00	11/8/00	11/14/00	02/08/01
ARSENIC	5.9	9.79	7.24	41.6			4.76	7.32		10.9		1.09		10.3	12.50
CADMIUM	0.596	0.99	0.676	4.21	0.13	0.76	1.4			1.18		0.05		0.18	0.15
COPPER	35.7	31.6	18.7	108	17.1	22.7	5.87	11.6	6	18.8	520	26.6		310	20.30
MERCURY	0.17	0.18	0.13	0.7											0.20
NICKEL	18	22.7	15.9	42.8				10.8	4.6	11.4	2.6	1.76		9.4	19.10
SILVER	1		0.733	1.77					1.93						95.30
PAHs (µg/kg)															
ACENAPHTHENE			6.71	88.9									21		
ACENAPHTHYLENE			5.87	128									36		
ANTHRACENE		57.2	46.9	245									115		
BENZO(A)ANTHRACENE	31.7	108	74.8	693	5090	4895							1020	2660	
BENZO(A)PYRENE	31.9	150	88.8	763	6500	6464				1194			1720	3270	
CHRYSENE	57.1	166	108	846	6850	6923				1165		514	2030	3680	
DIBENZ(AH)ANTHRACENE		33	6.22	135									338		
FLUORANTHENE	111	423	113	1494	13300	11596	1670			1992		1230	2930	2490	
FLUORENE		77.4	21.2	144									29		
NAPHTHALENE		176	34.6	391									11		
PHENANTHRENE	41.9	204	86.7	544	3400	3614							762	2180	
PYRENE	53	195	153	1398	9830	12656				1869		705	2310	4150	
Low molecular Weight PAHs			312	1442	3400	3614							973	2180	
High molecular Weight PAHs			655	6676	41670	42533	1670			6220		1744	10348	12140	
Total PAHs	4000	1610			68180	65049	1670		1307	7418		2449	24326	31210	

Highlighted data exceeds the EPA's probable effect level for effects to aquatic organisms.

Highlighted data exceeds at least one of the sediment quality criteria for effects to aquatic organisms.

1 TNRCC 2000. (Ecological Benchmarks for Freshwater) *in* Guidance for Conducting Ecological Risk Assessments at Remediation Sites in Texas. Draft Final. August 28, 2000. Texas Natural Resources Conservation Commission. Austin, Texas.

2 McDonald, D.D., C.G. Ingersoll, and T.A. Berger. 2000. Development and evaluation of consensus-based sediment quality guidelines for freshwater ecosystems. Archives of Environmental Contamination and Toxicology. Volume 39, pages 20-31. 2000 Springer-Verlag. New York Incorporated. TEC = Threshold of concern
The Sediment Quality Guidelines that were expressed on an organic carbon-normalized basis were converted to dry weight normalized values at 1% organic carbon.

3 EPA. 1997. The Incidence and Severity of Sediment Contamination in Surface Waters of the United States. EPA 823-R-97-006. September 1997. United States Environmental Protection Agency, Washington D.C.
TEL = Threshold Effects Level; PEL = Probable Effects Level)

Table 8. Metals sediment data from Barton Springs and Barton Creek. These sediment samples were taken from creek flow and spring discharge (when flow was turbid) during storm events. This large volume sediment sampling was conducted by the United States Geological Service in conjunction with the City of Austin. These data are from the City of Austin sediment quality database.

Screening Criteria / Location	Date	As mg/kg	Cd mg/kg	Cr mg/kg	Cu mg/kg	Hg mg/kg	Ni mg/kg	Pb mg/kg	Zn mg/kg
TNRCC[1]		5.9	0.6	37.3	35.7	0.17	18	35	123
Consensus TECs[2]		9.8	0.99	43.4	31.6	0.18	22.7	35.8	121
EPA TELs[3]		7.24	0.68	52.3	18.7	0.13	15.9	30.2	124
EPA PELs[3]		41.6	4.21	160	108	0.7	42.8	112	271
Barton Creek at Hwy. 71	05/26/99	**11.2**	0.540	**66.6**	**20.8**	0.06	**23.5**	**39.2**	**141**
Barton Creek at Hwy. 71	05/01/00	**6.78**	**1.90**	32.6	18.6		**30.2**	28.9	271
Barton Creek at Hwy. 71	06/09/00	**8.16**	0.349	37.2	12.8	0.03	**21.3**	15.7	57.6
Barton Creek above Barton Springs	05/18/99	**12.3**	0.483	**67.5**	**21.4**	0.07	**24.3**	**56.2**	**168**
Barton Creek above Barton Springs	05/26/99	**12.0**	0.546	**64.0**	**20.4**	0.09	**23.6**	**55.8**	**214**
Barton Creek above Barton Springs	05/02/00	**15.9**	**3.50**	**69.0**	31.1	**0.14**	**41.0**	**76.8**	326
Barton Creek above Barton Springs	06/09/00	**11.7**	**0.708**	**61.5**	**21.6**	0.04	**37.9**	**35.8**	301
Barton Creek above Barton Springs	11/03/00	**16.2**	**0.774**	**67.4**	**24.7**	0.03	**28.2**	**56.8**	**210**
Barton Springs	05/01/00	**22.3**	0.406	**80.7**	**38.0**	0.08	**40.1**	31.7	113
Barton Springs	05/02/00	**19.3**	0.315	**67.5**	**27.8**	0.09	**34.6**	24.6	120
Barton Springs	06/10/00	**17.8**	0.372	**82.1**	**26.5**	0.07	**40.5**	21.3	87.8
Eliza Springs	11/03/00	**19.8**	**0.965**	**71.8**	**63.2**	0.02	**37.7**	34.8	**138**

Highlighted data equals or exceeds the EPA's probable effect level for effects to aquatic organisms.

Highlighted data equals or exceeds at least one of the sediment quality criteria for effects to aquatic organisms.

1 TNRCC 2000. (Ecological Benchmarks for Freshwater) *in* Guidance for Conducting Ecological Risk Assessments at Remediation Sites in Texas. Draft Final. August 28, 2000. Texas Natural Resources Conservation Commission. Austin, Texas.

2 McDonald, D.D., C.G. Ingersoll, and T.A. Berger. 2000. Development and evaluation of consensus-based sediment quality guidelines for freshwater ecosystems. Archives of Environmental Contamination and Toxicology. Volume 39, pages 20-31. 2000 Springer-Verlag. New York Incorporate. TEC = Threshold of concern
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3 EPA. 1997. The Incidence and Severity of Sediment Contamination in Surface Waters of the United States. EPA 823-4-97-006. September 1997. United States Environmental Protection Agency, Washington D.C.
TEL = Threshold Effects Level; PEL = Probable Effects Level)

Table 5 Polycyclic-aromatic hydrocarbon (PAH) sediment data from Barton Springs Pool and Barton Creek. These sediment samples were taken from creek flow and spring discharge (when flow was turbid) during storm events. This large volume sediment sampling was conducted by the United States Geological Survey in conjunction with the City of Austin. These data are from the City of Austin sediment quality database.

Screening Criteria / Location	Date	Total PAH µg/kg	Naphthalene µg/kg	Fluorene µg/kg	Phenanthrene µg/kg	Anthracene µg/kg	Fluoranthene µg/kg	Pyrene µg/kg	Benzo(a)-anthracene µg/kg	Chrysene µg/kg	Benzo-(a)pyrene µg/kg
TNRCC[1]		4,000			41.9		111	53	31.7	57.1	31.9
Consensus TECs[2]		1610	176	77.4	204	57.2	423	195	108	166	150
EPA TELs[3]			34.6	21.2	86.7	46.9	113	153	74.8	108	88.8
EPA PELs[3]			391	144	544	245	1494	1398	693	846	763
Barton Creek at Hwy. 71	05/26/99	725	13.9		18.5	17.0	37.1	40.2	26.3	23.2	41.7
Barton Creek at Hwy. 71	05/01/00	819	3.2	16.1	16.8	N/A	31.7	29.3	26.8	29.3	36.6
Barton Creek at Hwy. 71	06/09/00	96	2.0	0.3	2.7	0.9	5.5	4.4	2.5	3.6	2.9
Barton Creek at Hwy. 71	11/3-11/4/00	514					40.3	33.9		32.8	
Barton Creek above Barton Springs	05/18/99	8,025	6.4	10.6	333	37.9	1023	833	303	644	492
Barton Creek above Barton Springs	05/26/99	21,418	18.0	24.1	799	103.1	2749	2320	808	1718	1289
Barton Creek above Barton Springs	05/02/00	22,918	26.4	39.3	786	75.0	2143	1679	679	1679	1179
Barton Creek above Barton Springs	06/09/00	5,332	6.0	5.8	209	19.9	635	512	237	464	351
Barton Creek above Barton Springs	11/3-11/4/00	15,847			408		1560	1220	440	1170	990
Barton Springs	05/26/99	86	0.4		3.6	1.1	10.0	8.8	3.4	6.4	5.1
Barton Springs	05/01/00	389	1.8		12.2		38.9	33.3	12.2	30.6	24.7
Barton Springs	05/02/00	481	1.0	4.3	12.3		34.3	28.6	12.9	31.4	24.3
Barton Springs	06/09/00	201	1.2	0.2	3.8	1.9	12.7	11.7	6.7	11.1	9.8
Barton Springs	06/10/00	232	4.5	0.6	5.0	2.8	17.0	15.3	7.8	13.5	12.8
Barton Springs	11/03/00	386									
Eliza Springs	11/03/00	1547									

Highlighted data exceeds the EPA's probable effect level for effects to aquatic organisms.

Highlighted data exceeds at least one of the sediment quality criteria for effects to aquatic organisms.

1 TNRCC 2000. (Ecological Benchmarks for Freshwater) *in* Guidance for Conducting Ecological Risk Assessments at Remediation Sites in Texas. Draft Final. August 28, 2000. Texas Natural Resources Conservation Commission. Austin, Texas.

2 McDonald, D.D., C.G. Ingersoll, and T.A. Berger. 2000. Development and evaluation of consensus-based sediment quality guidelines for freshwater ecosystems. Archives of Environmental Contamination and Toxicology. Volume 39, pages 20-31. 2000 Springer-Verlag. New York Incorporated. TEC = Threshold of concern
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3 EPA. 1997. The Incidence and Severity of Sediment Contamination in Surface Waters of the United States. EPA 823-R-97-006. September 1997. United States Environmental Protection Agency, Washington D.C. TEL = Threshold Effects Level; PEL = Probable Effects Level)

Table 1(esticide sediment data from Barton Springs Pool. These sedimer nples were taken from creek flow and spring discharge (when flc as t... oid) during storm events. This large volume sediment sampling wa. conducted by the United States Geological Survey in conjugation w..h the City of Austin. These data are from the City of Austin sediment quality database.

Screening Criteria / Location	Date	Chlordane µg/kg	DDE µg/kg	DDD µg/kg
TNRCC[1]		4.0	1.42	3.54
Consensus TECs[2]		3.2	3.16	4.88
EPA TELs[3]		2.3	2.07	1.22
EPA PELs[3]		4.8	374	7.81
Barton Creek at Hwy. 71	05/26/99	123.6		
Barton Creek at Hwy. 71	05/01/00	63.4		
Barton Creek at Hwy. 71	06/09/00	5.5		
Barton Creek above Barton Springs	05/18/99		**2.61**	
Barton Creek above Barton Springs	05/26/99	48.1	**7.56**	

(shaded)	Highlighted data exceeds the EPA's probable effect level for effects to aquatic organisms.
	Highlighted data exceeds at least one of the sediment quality criteria for effects to aquatic organisms.
1	TNRCC 2000. (Ecological Benchmarks for Freshwater) *in* Guidance for Conducting Ecological Risk Assessments at Remediation Sites in Texas. Draft Final. August 28, 2000. Texas Natural Resources Conservation Commission. Austin, Texas.
2	McDonald, D.D., C.G. Ingersoll, and T.A. Berger. 2000. Development and evaluation of consensus-based sediment quality guidelines for freshwater ecosystems. Archives of Environmental Contamination and Toxicology. Volume 39, pages 20-31. 2000 Springer-Verlag. New York Incorporated. TEC = Threshold of concern The Sediment Quality Guidelines that were expressed on an organic carbon-normalized basis were converted to dry weight normalized values at 1% organic carbon.
3	EPA. 1997. The Incidence and Severity of Sediment Contamination in Surface Waters of the United States. EPA 823-R-97-006. September 1997. United States Environmental Protection Agency, Washington D.C. TEL = Threshold Effects Level; PEL = Probable Effects Level)

Table Metals, poly-aromatic hydrocarbon (PAH), and pesticide sedime[illegible] [illegible]nple data from Barton Creek upstream of Barton Springs pool. T[illegible] data were from grab samples taken from the bottom of the stream. These data are from the City of Austin sediment quality database.

	TNRCC	Consensus TECs	EPA TEL	EPA PEL	Barton Creek Campbell Hole Pool	Barton Creek below Spyglass	Barton Creek above Spyglass	Barton Creek Recharge Pool	Barton Creek Lost Creek	Barton Creek Short Spring	Barton Creek Johnson Pool	Barton Creek below BCT	Barton Creek above BCT	Barton Creek Shield Pool	Barton Creek Stark Pool
metals (MG/KG)					09/26/00	06/17/99	06/17/99	07/20/00	08/26/99	04/17/98	07/19/00	02/23/99	02/23/99	05/20/94	07/19/00
ARSENIC	5.9	9.79	7.24	41.6	5.17	3.65	5.88	7.16		10.491	11.5			23.78	6.47
CADMIUM	0.596	0.99	0.676	4.21	0.194	0.187	0.137	0.0907		0.103	0.223			32.73	0.0884
CHROMIUM	37.3	43.4	52.3	160	3.02			3.45	2.1	4.1069	9.16	3.66	3.15	25.18	9.56
COPPER	35.7	31.6	18.7	108	17.8	8.81	6.73	2.18	1.8	3.58	5.88	14.8	4.51		5.36
LEAD	35	35.8	30.2	112	40.2	11	13.9	3.27		6.32	7.96				7.33
MERCURY (UG/KG)	0.174	0.18	0.13	0.696	111										
NICKEL	18	22.7	15.9	42.8	9.4	7.28	6.6	7.81	2.3		8.51				14.1
SILVER	1		0.733	1.77					0.78			3.6	2.84		
ZINC	123	121	124	271	73	52.9	38.4	30.4	21	25.7	31.2	26.5	19	28.25	48.9
PAHs (UG/KG)															
ANTHRACENE															
BENZO(A)ANTHRACENE			6.71	88.9											
BENZO(B)FLUORANTHENE			5.87	128											
BENZO(B+K)FLUORANTHENE										1,838					
BENZO(K)FLUORANTHENE	31.7	108.0	74.8	693											
BENZO(GHI)PERYLENE						1,497									
BENZO(A)PYRENE	31.9	150.0	88.8	763											
CHRYSENE	57.1	166.0	108	846											
DIBENZ(AH)ANTHRACENE		33.0	6.22	135											
FLUORANTHENE	111.0	423.0	113	1494		3,004	558			1,904					
INDENO(1_2_3-CD)PYRENE						1,458									
PHENANTHRENE	41.9	204.0	86.7	544		1,124									
PYRENE	53.0	195.0	153	1398						1,978					
Total PAHs	4,000	1,610				7,083	558			5,720					

Highlighted data exceeds the EPA's probable effect level for effects to aquatic organisms.

Highlighted data exceeds at least one of the sediment quality criteria for effects to aquatic organisms.

1 TNRCC 2000. (Ecological Benchmarks for Freshwater) *in* Guidance for Conducting Ecological Risk Assessments at Remediation Sites in Texas. Draft Final. August 28, 2000. Texas Natural Resources Conservation Commission. Austin, Texas.

2 McDonald, D.D., C.G. Ingersoll, and T.A. Berger. 2000. Development and evaluation of consensus-based sediment quality guidelines for freshwater ecosystems. Archives of Environmental Contamination and Toxicology. Volume 39, pages 20-31. 2000 Springer-Verlag. New York Incorporated. TEC = Threshold of concern
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Table 17 etals, poly-aromatic hydrocarbon (PAH), and pesticide sediment ple data from Barton Creek upstream of Barton Springs pool. Tl data w..e from grab samples taken from the bottom of the stream. These are from the City of Austin sediment quality database.

	TNRCC[1]	Consensus TEC's[2]	EPA[3] TELs	EPA[3] PELs	Barton Creek Sunken Garden	Barton Creek Above BS Pool	Barton Creek Above BS Pool	Barton Creek Above BS Pool	Barton Creek Above BS Pool	Barton Creek Above BS Pool	Barton Creek Between Dams	Barton Creek Between Dams	Barton Creek Between Dams	Barton Creek Between Dams	Barton Creek Between Dams
metals (MG/KG)'					03/22/99	11/21/94	04/20/95	04/20/95	09/04/97	04/28/98	07/09/96	09/04/97	04/28/98	08/26/99	07/06/00
ARSENIC	5.9	9.79	7.24	41.6	5.42	.			.		.	2.44	.	.	13.9
CADMIUM	0.596	0.99	0.676	4.21	2.66	.	0.13	0.85	.	2.47	1.01	.	2.4	.	0.172
CHROMIUM	37.3	43.4	52.3	160	7.41	.	.	.	.	7.79	.	.	12.9	2.2	
COPPER	35.7	31.6	18.7	108	21	9.47	6.4	7.94	.	3.88	10.05	.	4.71	3.4	4.59
LEAD	35	35.8	30.2	112	12.7	20.76	14.8	22.98	6.2	48	14.99	.	10.8	6.5	12.7
NICKEL	18	22.7	15.9	42.8	7.29	.	.	.	.	.	.	.	.	1.6	8.59
SILVER	1		0.733	1.77	.	.	.	.	.	1.44	.	.	0.76	.	.
ZINC	123	121	124	271	39.5	56.7	36.7	41.52	8.36	21.3	65.4	10.5	35.4	26	42.6
pahs (UG/KG)'															
ANTHRACENE					.	724	.	.	.	.	.	.	.	.	.
BENZO(A)ANTHRACENE			6.71	88.9	.	12,631	4,270	4,628	.	.	.	8,350	.	1,100	1,300
BENZO(B)FLUORANTHENE			5.87	128	.	16,543	7,550	9,152	5,110	.	.	9,210	.	1,840	2,410
BENZO(K)FLUORANTHENE	31.7	108.0	74.8	693	.	11,159	5,050	3,378	.	.	.	4,190	.	508	1,470
BENZO(GHI)PERYLENE					.	17,981	4,800	3,253	.	.	.	4,920	.	1,400	.
BENZO(A)PYRENE	31.9	150.0	88.8	763	.	3,946	6,880	6,393	.	.	.	.	.	1,350	1,790
CHRYSENE	57.1	166.0	108	846	.	15,551	5,860	6,873	.	.	.	3,470	.	1,840	2,350
DIBENZ(AH)ANTHRACENE		33.0	6.22	135	.	6,949	.	.	.	.	.	1,340	.	.	.
FLUORANTHENE	111.0	423.0	113	1494	.	25,891	10,200	10,048	8,380	.	.	9,370	.	2,790	1,780
INDENO(1_2_3-CD)PYRENE					.	17,216	4,070	3,657	.	.	.	3,710	.	1,290	1,870
PHENANTHRENE	41.9	204.0	86.7	544	.	6,956	1,820	2,419	.	.	.	2,810	.	925	985
PYRENE	53.0	195.0	153	1398	.	25,347	7,360	11,428	5,460	.	.	9,010	.	2,250	4,420
Total PAHs	4,000	1,610				160,893	56,860	61,225	16,930			56,380		15,293	18,355
pesticides (UG/KG)'															
P_P'-DDD	3.54	4.88	1.22	7.81	.	746	.	.	.	.	.	.	.	.	.
P_P'-DDE	1.42	3.16	2.07	374	.	7.6	.	.	.	.	.	.	.	.	.
P_P'-DDT	1.19	4.16	1.19	4.77	.	25.3	.	.	.	.	.	.	.	.	.
ALDRIN	2				.	27.9	.	.	.	.	.	.	.	.	.
ENDRIN	2.67	2.22			.	530	.	.	.	.	.	.	.	.	.
HEPTACHLOR EPOXIDE	0.6	2.47			.	5.07	.	.	.	.	.	.	.	.	.
BETA-BHC	5		3.2	9.9	.	.	.	.	114	.	.	175	.	.	.
DELTA-BHC			3.2	9.9	.	559	.	.	.	.	.	.	.	.	.
GAMMA-BHC (LINDANE)	0.94	2.37	3.2	9.9	.	17.7	.	.	.	.	.	.	.	.	.
PCB	0.0341				0.09	.	.	.	.	.	.	.	.	.	.

Highlighted data exceeds the EPA's probable effect level for effects to aquatic organisms.

Highlighted data exceeds at least one of the sediment quality criteria for effects to aquatic organisms.

1 TNRCC 2000. (Ecological Benchmarks for Freshwater) *in* Guidance for Conducting Ecological Risk Assessments at Remediation Sites in Texas. Draft Final. August 28, 2000. Texas Natural Resources Conservation Commission. Austin, Texas.

2 McDonald, D.D., C.G. Ingersoll, and T.A. Berger. 2000. Development and evaluation of consensus-based sediment quality guidelines for freshwater ecosystems. Archives of Environmental Contamination and Toxicology. Volume 39, pages 20-31. 2000. TEC = Threshold of concern
The Sediment Quality Guidelines that were expressed on an organic carbon-normalized basis were converted to dry weight normalized values at 1% organic carbon.

3 EPA. 1997. The Incidence and Severity of Sediment Contamination in Surface Waters of the United States. EPA 823-R-97-006. September 1997. United States Environmental Protection Agency. Washington D.C. (TEL = Threshold Effects Level; PEL = Probable Effects Level)

Table 13. Average Values of Trace Metals in Springs Sediments.

Parameter	Low (mg/kg)	High (mg/kg)
Arsenic	3.963	8.483
Cadmium	0.3985	0.1754
Copper		3.5125
Lead	8.713	26.57
Nickel	6.82	10.23
Zinc	15.35	44.6

Table 14. Estimates of Increase in Developed Acres

Source	Annual Average	July 1998 to July 2003 (Term of CGP)	April 2002 to July 2003 (Remainder of CGP)
TXCABA	480	2,400	600
Service	1,000-2,500	5,000-12,500	1,250-3,125
LCRA	1,641	8,205	2,051
Range of All Estimates	480-2,500	2,400-12,500	600-3,125